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TECHNICAL REPORT NO. TR-AC-16

THE SOVIET YAK-11 AIRPLANE

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SUMMARY

THE SOVIET YAK-11 AIRPLANE

PURPOSE

A. To determine the physical characteristics of a modern YAK-11 airplane.

B. To report changes found in the modern YAK-11 by comparing an earlier model which was examined by the British in early 1949 and reported in ADI Tech Paper No. 2/49.

C. To prepare a brief analysis of the Soviet capabilities in the production of the YAK-11.

D. To weigh the airplane and components and prepare a weight statement.

FACTUAL DATA

The YAK-11 was a Hungarian aircraft which crash landed near Siegenburg, Germany, on 24 February 1952. This aircraft was inspected by an ATLO team in April 1951. An Air Intelligence Information Report, AF No. 302233, and Crash Report, NAD-81740, were written by the above group. The aircraft components were disassembled, examined, and replaced by the above team since the Hungarians requested the return of the airplane. Negotiations were undertaken for its return but it was finally relinquished to the USAF. The aircraft was received by the Air Technical Intelligence Center on 30 October 1951, from USAFE. Interrogation of the Hungarian pilots revealed that the airplane was fabricated in the Soviet Union during 1950 and the final assembly of six components was accomplished in Budapest, Hungary, in November 1950.

In making the crash landing, the Hungarian pilots damaged the lower cylinders of the engine, the propeller, propeller hub, the leading edge of the right wing, the oil cooler ducting, and the engine mount ring forward of the firewall.

The Air Technical Intelligence Center examined and disassembled the aircraft to perform a detailed analysis. Since this report was primarily concerned with material and component analysis, a performance section was not included within.

DISCUSSION

The YAK-11 is a single engine, tandem seat, low wing monoplane with conventional retractable main landing gear, fixed tail wheel and a single fin and rudder. This aircraft is normally used for training and is a counterpart of the USAF T-6 aircraft. It is built by the Soviets and used by their own and their satellites air forces. The fuel is carried in two main wing tanks of 173 liters (45.7 gal) each and a small sump tank of 13.5 liters (3.6 gal).

Wing Span	30' 10"
Wing Area	165.7 sq ft
Aspect Ratio	$\frac{b^2}{S} = \frac{950.5}{165.7} = 5.74$
Length	27' 11"
Engine - Model	ASh-21 7 cylinder radial air cooled engine
Take-off Rating	690 HP
Take-off RPM	2300 RPM
Total Fuel Capacity	95 gal
Total Oil Capacity	10 gal
Weight Empty	3811#
Gross Weight - Full Fuel, Oil, and Ammo (No Bombs)	5055#
Gross Weight - Full Fuel, Oil, and Ammo, Plus 2-110# (Bombs)	5275#
Wing Loading Normal	$\frac{5055}{165.7} = 30.5\#/ft^2$
Power Loading Normal	$\frac{5055}{690} = 7.33\#/hp$
Wing Loading - Bomber	$\frac{5275}{165.7} = 31.8\#/ft^2$
Power Loading Bomber	$\frac{5275}{690} = 7.64\#/hp$

General improvements over earlier constructed aircraft which were previously examined are: the fuselage is partly covered by metal replacing plywood, the use of a flush mounted iron core antenna replacing the iron loop type, new instruments are incorporated into the pilots and copilots instrument panel, and provisions for a new gun sight computing system is used.

The wing is constructed in two panels except for the detachable wing tips. It is a conventional two spar and rib construction with a metal stressed skin which is flush riveted. The ailerons are metal frames with a fabric covering. The flaps extend from the fuselage outboard to the ailerons. They are a split type with mechanical up locks linked to the pneumatically actuated push pull tube. The above locks are spring loaded locking the flaps in the up position.

Hinged metal inspection panels on both sides of the fuselage permit easy access to the controls and lines in both cockpits.

The main landing gear is a conventional type and retracts inward. In the retracted position this gear is housed in front of the main spar. The operation of extending, retracting and wheel braking is accomplished by pneumatic power. A mechanical up lock keeps the gear in the retracted position. The self-locking actuating cylinder and the geometric lock formed by the side brace in the extended position act as a positive downlock. A mechanical indicator which moves vertically through the upper surface of the wings is a visual check for landing gear position. The tail wheel is free to caster when the control stick is pushed forward. The mechanical lock may be engaged by pulling back on the control stick.

All of the aluminum alloy sheet materials were equivalent to 17s alclad. In general, the sheet was fine-grained, good quality material with normal solution heat-treated structures. All sheet stock in addition to being alclad was anodized and chromate sealed. Extrusions were also of 17s type material; rivets were equivalent to A17s. The forgings were approximately the same as U. S. 14s aluminum used in the solution heat-treated and artificially aged condition; wide variation in-grain size was noted.

All of the low alloy steel samples from the airframe were of the 1% chromium, 1% manganese, and 1% silicon type varying only in carbon content. This steel was used for fuselage structural tubing and engine mount, as well as highly stressed nuts and bolts. This type of steel called "Chromansil" is used widely in Soviet aircraft, e. g., MIG-15, and IL-10. Its chief advantage is its low critical alloy content; the disadvantages being its temper brittleness and low hardenability. Stainless steel similar to AISI321 was used in the engine cowling and the exhaust duct; the quality was satisfactory. Although the quality of weldments varied, they were considered adequate for the purpose intended.

The practice of using welded tubular fuselage structure is considered obsolete by American standards but is an advantage in the Soviet aircraft industry. The wing spars are built-up sections.

In general, the plastic materials were largely used in non-critical applications. The bakelite, nitrocellulose, and transparent materials examined were adequate to do the job for which they were intended. A practice not acceptable to U. S. standards was the use of a flammable plastic for a main fuel line transfer hose cover.

During the analysis of the rubber parts four types were identified: natural, polybutadiene, butadiene-styrene, and neoprene. Polybutadiene, used for the fuel transfer hose and an oil hose, is considered to be a poor choice because this type is not fuel resistant; neoprene used to some extent would have been a better material, although inferior to Buna N. Butadiene-styrene (Buna S) rubber was used for wire insulation; this is considered a good choice of materials.

The ASh-21 engine is installed in a conventional manner but incorporates movable shutters on the nose section of the engine for controlling the air cooling inlet diameter.

From a manufacturing standpoint the most critical powerplant parts are gears, cylinder heads, and crankcase main sections. The gears had been ground with a Maag gear tooth grinder. The employment of a Maag gear tooth grinder has several advantages which are as follows: durability of the precision gears is enhanced through more effective lubrication, the probability of scrap during manufacture is decreased since it is less likely that the tooth surfaces will be burned during the grinding operation.

In the ASh-21 counterpart of the Wright Cyclone 7, the casting method of fabrication of the cylinder heads was employed in favor of forging. This may be considered to impose an optimum limit on engine power potential. The same may be said for the employment of aluminum alloy instead of steel in the crankcase main sections.

The armament of the YAK-11 consists of one fixed 12.7mm Berezina machine gun. This machine gun is mounted to the left of the c .cer line of the aircraft beneath the front fuselage panel. The Berezina is synchronized to the engine and fires forward through the propeller arc. The gun and sight head were missing from this aircraft. The component parts of the fire control system are similar to those used in a computing sight. Provision for carrying 2-110 or 220# bombs is provided by a bomb shackle on the underside of each wing. There was no provision for armor protection for the pilots since it is a training craft.

The radio navigation equipment consists of an RPK-10M Direction Finding Receiver with a iron core, stationary, loop antenna flush mounted in the top of the fuselage behind the rear cockpit. The communication equipment consists of an RSI-6M-1 Receiver, RSI-6K Transmitter and Interphone Amplifier. A wire antenna extending from a mast at the rear of the cockpit to the vertical stabilizer services the High Frequency Transmitter, High Frequency Receiver and the Direction Finding Receiver.

The electronic equipment has been removed from the YAK-11 airplane; installed first in an operational YAK-9P Soviet plane and is presently being installed in a U. S. fighter plane.

One of the purposes of this installation is to test the flight operational performance of the equipment and, although the tests are not at present complete, some indication of expected results have been obtained.

In these preliminary tests, operational range tests of air-to-ground communications were made employing a Type BC-610 transmitter and a Hammarlund Super-pro receiver as the ground station.

The cockpit arrangement is compact, simple, and similar to the YAK-9P. The front instrument panel contains more instruments than the rear panel. A few of the controls and instruments are duplicated in the rear cockpit. The aircraft must be flown by a pilot from the front cockpit. A bucket type seat with belt and shoulder strap attachment is used. Forward and aft vision from the front cockpit is good. No provision is made for cockpit heating. Front cockpit ventilation is accomplished by means of an air scoop at the base of the front windshield which is controlled by turning a knob to the right of the sight mount. Rear cockpit ventilation is also accomplished by an air scoop. This scoop is located on the right side of the fuselage beneath the canopy guide rails. A lever on the right side of the cockpit controls the opening and closing of the scoop. The control stick of the front cockpit contains a bomb release button on top, a trigger switch, and a brake handle. The brake handle is employed to meter air to the brake selected by the position of the rudder bar.

The engine controls are located on the left hand console which is the same as USAF practice in fighter aircraft. The rear cockpit control stick contains a button at the top of the pistol grip which the instructor may use to keep air from entering the brakes or bleed air from the brake system. This safety feature prevents the student from ground looping the aircraft.

The YAK-11 employs a pneumatic system for actuation of the landing gear, flaps, brakes, engine starting, shutters, gun chargers, and firing units. The source of air includes normal and emergency air storage tanks. The pressure in these tanks is maintained by an engine driven air compressor. Provisions are made for using an external source of air on the ground. The ground filler is located on the left side of the fuselage under the aft inspection panel.

Plastic materials were found where its application was not critical and the choice of material could be dependent upon availability or ease of forming.

CONCLUSIONS

The airplane is well designed structurally and aerodynamically resulting in a maximum movement of the c. g. of 2.3 inches for the worst load condition studied.

The air starting system employed is a positive simple method for starting the aircraft engine. The pneumatic system is also simple, effective, accessible, and easily maintained. The YAK-11 pneumatic system incorporates filters but no desiccators for processing the air supplied to the system. For cold weather operation the pneumatic system encounters no added difficulties.

Satisfactory two-way daytime communication was maintained with the test plane at an average distance of 85 miles from the ground station. The ground station could be heard at a range of 200 miles on the RSI-6M-1 receiver.

For homing purposes the RPKO-10M equipment compared favorably with the standard U. S. AN/ARN-6 radio compass installation during preliminary flight tests. In some instances, greater homing ranges were possible with the RPKO-10M than with AN/ARN-6 equipment. In addition, the pilot expressed a definite preference for the Soviet equipment because of the simplicity of operation, and excellent visual homing presentation even at maximum ranges. The Soviet equipment has also demonstrated its ruggedness and reliability, having required no maintenance whatever since it was received.

Gunnery training is probably conducted in this aircraft in order to familiarize the pilot with a gyro stabilized computing gun sight prior to his being assigned to jet type aircraft.

Aluminum alloys, low alloy steel, stainless steels, and resistance welds were all of good quality, adequate for the purpose intended. A major fire hazard was introduced when flammable cellulose materials were used in the manufacture of a fuel hose. The cellulose materials were used to give fuel resistance to a non-resistant rubber. The fuel and oil transfer hose was fabricated from a non-oil-resistant material, polybutadiene. However, in general the rubber material was of good quality.

The production breakdown of the airplane indicated that it is adaptable to mass production. The production can be done cheaply and easily with relatively unskilled labor. A greater variety of welding was used in the manufacture of the YAK-11 than had been found on other Soviet aircraft. The quality of the riveting was good. Welded steel brackets were used to a great extent contrary to the American practice of forgings and castings. More attention was given to protective finishes on the YAK-11 than has been found on other Soviet aircraft examined. In making a comparison regarding the manufacturing philosophy of the YAK-11 fighter trainer and the MIG-15 interceptor, it is strongly suggested that because of longer service life desired of the YAK-11 the Soviets placed emphasis on its overall quality. On the other hand the MIG-15 is a combat aircraft with a shorter service life; therefore, emphasis was placed on functional quality and only in those areas considered critical. This is further illustrated by the protection of alclad aluminum alloy sheet with anodic and chromate treatment.

The ASh-21 is wholly adaptable to modern quantity production methods and processes. The reason for retention of the casting method of fabrication of cylinder heads in favor of the forging method is unknown. The fact that the casting is still practiced may be considered to impose a limit on optimum engine power potential.

RECOMMENDATIONS

None

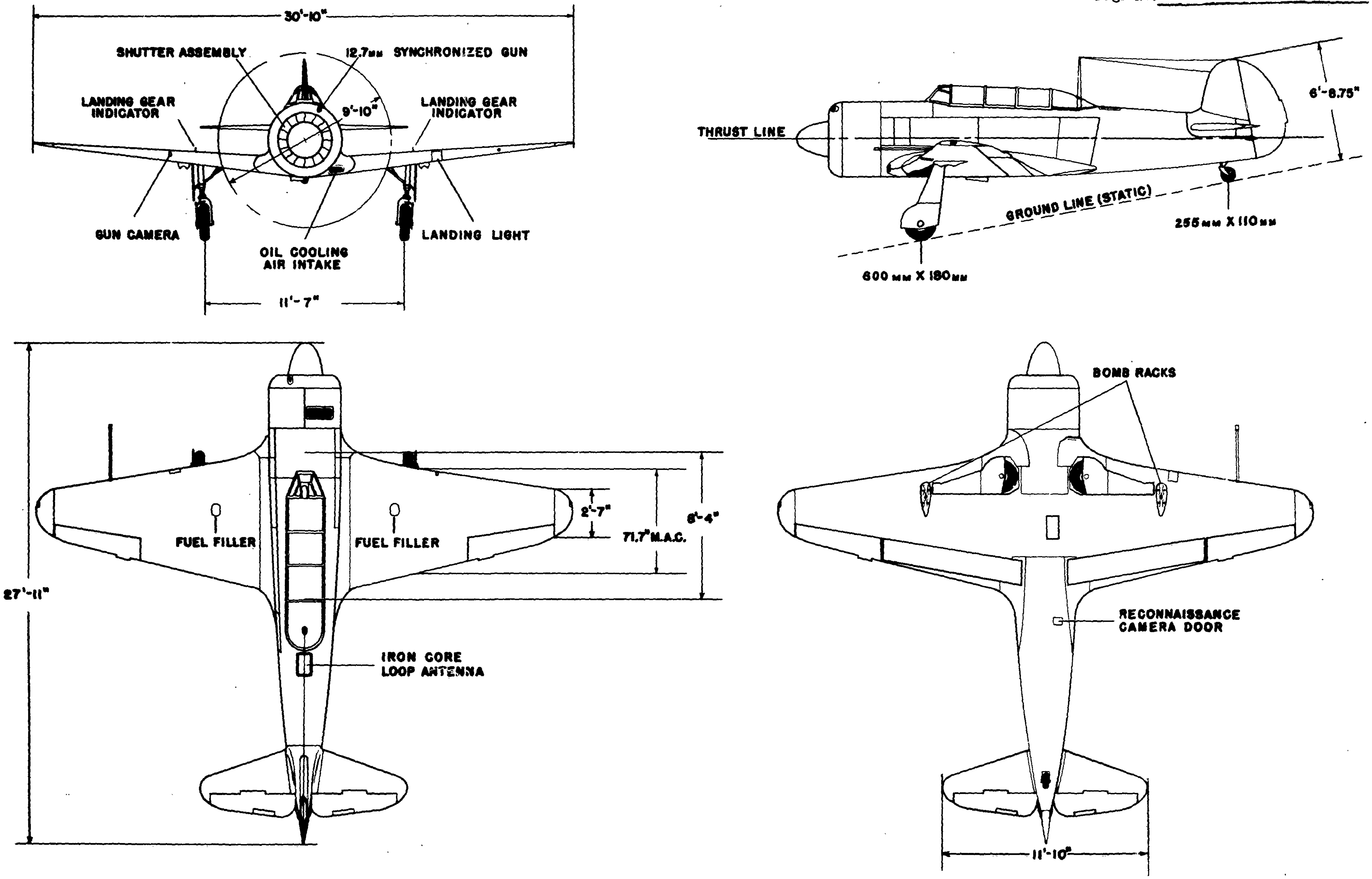

Fig. 1 Four View Drawing

SECTION I

AIRFRAME

A. WING GROUP

The wing is constructed in two panels except for the detachable wing tips. It is a conventional two spar and rib construction with a metal stressed skin which is flush riveted. The built up spars are spliced at the centerline of the airplane. The upper and lower surfaces of the center section between the front and rear spars are metal covered. The stiffeners are of the spanwise type.

The two forward attachment points to the fuselage are located on the web of the front spar. The two center fuselage attachment points are located approximately midway between the front and rear spars on the upper wing surface directly over the heavy root ribs. The two aft fuselage attachment points are placed on the web of the rear spar. See Fig 50.

The main landing gear attachment fitting is located on the front face of the forward spar, at the intersection of the second rib. The front spar is perpendicular to the centerline of the airplane out to the first rib at which point it bends aft.

The upper surface of the wing bounded by the front and rear spars and the heavy root ribs is covered by wing skin. The lower surface of the wing as outlined in the preceding sentence is covered by a removable metal panel. Within this section of the wing is located the fuel sump tank, oil cooler, ducting, and the main air storage tank. The detailed locations of the items described can be found in Aircraft Systems Section of this report. See Fig 50 and 53.

The leading edge section of the wing housing the landing gear is reinforced by spanwise and cordwise stiffeners. In the leading edge of the right wing panel, provision is made for the installation of a gun camera. A landing light is recessed in the leading edge of the left wing panel.

The ailerons are of a metal frame construction with a fabric covering. A ground set trim tab is utilized on the ailerons. The flaps are all metal construction and extend from the wing root outboard to the ailerons. They are a split type with mechanical up locks linked to the pneumatically actuated push pull tube. The above locks are spring loaded locking the flaps in the up position.

B. EMPENNAGE GROUP

The vertical and horizontal stabilizers are of conventional metal construction and configuration. The stabilizers are also of the two spar and rib construction with metal skin which is flush riveted. The elevators are metal frames with a fabric covering. The rudder has a tube as the basic load carrying member. Metal ribs are attached to the tube. The lower portion of the rudder is covered with a metal sheet. The entire rudder including the metal sheet is fabric covered. The metal sheet covering is used for resistance to stones thrown up from the tail wheel. A ground set trim tab is utilized on the rudder. The rudder is attached to the fin at two hinge points, and to the fuselage at one point. The rudder has no static or aerodynamic balance. The elevator trim tab is mechanically actuated and controlled from the cockpit.

The horizontal stabilizer is mounted above the upper longerons of the fuselage and is attached by bolts at four places. The front spar of the fin is bolted to the stabilizer and the rear spar of the fin is bolted to the fuselage. See Fig 54. Approximately one-third of the span of the elevator is used for aerodynamic balance. The use of a lead weight suspended on an overhung arm contributes to the static balance. See Fig 55.

C. BODY GROUP

The fuselage is a welded tubular steel structural framework with metal stringers and formers having a metal and fabric covering. The attachment points for the engine mount, the wings, tail, tail wheel, and other minor brackets are welded to this structure. See Fig 51.

The engine mount is also of the welded tubular steel construction and is attached to the fuselage by the use of four bolted connections.

The cockpit enclosure consists of a fixed windshield, movable portion for pilot egress and ingress, a fixed section, a movable portion for co-pilot egress and ingress and a fixed rear section. The entire enclosure is covered with a formed transparent material. A section of transparent material is also used to cover the recessed iron loop antenna housing.

The juncture of the wings and tail with the body group is neatly faired with removable fillets.

Metal skin is used around the perimeter of the fuselage aft of the firewall to the windshield, a band beneath the canopy, and the curved surface extending from the aft end of the canopy to the empennage. Metal inspection panels on the fuselage are used as skin. These panels are located as follows: On the right and left side of the fuselage to expose the front cockpit, the left side to expose the rear cockpit, and on the left side to expose the radio compartment. See Fig 56 and 57. Fabric was used to cover the remaining portion of the fuselage. Hat section stringers are used to catch the stitching of the fabric. Tape is cemented to the outer surface to conceal the stitches.

The fuselage inspection panels provide easy access to the controls and lines in both cockpits.

D. ALIGHTING GEAR

The alighting gear consists of the main landing gear, which is of the conventional side folding configuration, and a fixed tail wheel installation which is free to swivel. The main gear is pneumatically retracted and is covered with flush doors. The tire size is 600 mm x 180 mm. See Fig 58.

The main landing gear retracts inward and is housed forward of the front spar within the leading edge of the wing. A mechanical up lock keeps the gear in the retracted position. The self-locking actuating cylinder and a geometric lock formed by the side brace in the extended position act as a positive down lock. A mechanical indicator which moves vertically through the upper surface of the wings is a visual check for the landing gear position.

The landing gear doors, which are attached to the main strut, consist of two sections. The upper section is rigidly attached to the strut and the lower section to the piston assembly.

The landing gear struts are of the air-oil type where an air spring is used for taxiing and landing impact is absorbed by forcing oil through the strut orifices. The struts contain no metering pins. The orifice plate rather than having a single hole, as is customary in this country, has five holes of the same diameter equally spaced around the orifice plate. The packings are the chevron type and appear to be no different in design than the chevrons that were formerly used in this country. A felt wiper is used in the gland nut although no scraper ring is used. The piston tube and axle bearing diameters are chrome plated. The torque arm pins and up lock roller are also chrome plated.

The tail wheel assembly is located on the aft section of the fuselage. The tire size is 255 mm x 110 mm. The mechanical tail wheel lock may be engaged by pulling back on the cockpit control sticks. The wheel is free to swivel when the control is pushed forward. This lock is the same type that is incorporated on the YAK-9P.

The tail gear assembly consists of a air-oil type of strut, piston and a tail wheel fork.

SECTION II

POWER PLANT INSTALLATION

The airplane is powered by a single 7 cylinder radial air cooled engine having a single speed internal supercharger. See Fig 2. The engine has a take-off rating of 690 BHP at 2300 RPM at sea level. The engine is fitted with a two-bladed, aluminum constant speed type propeller. This propeller utilizes a governor and counter balances for pitch control. The oil radiator is mounted in the wing forward of the front spar. The oil tank is mounted on the right side of the fuselage aft of the firewall. The grade of fuel specified is 89 octane. The fuel is carried in 3 internal wing tanks having a combined capacity of 95 gallons. The fuel is gravity fed to a sump tank mounted aft of the front spar under the center of the wing. No purging is utilized. The tanks are all vented together. Starting of the engine is accomplished by compressed air.

A. ENGINE INSTALLATION

The ASh-21 engine is a 7 cylinder radial, air cooled engine with a piston displacement of 1260 cu. in. A single speed centrifugal type of supercharger having a 7:1 drive ratio is incorporated in this engine. Fuel is injected into each cylinder head by a seven cylinder fuel injection pump provided with an automatic mixture control unit and a manifold pressure regulator. Conventional accessory drives are provided at the rear and front sections of the engine. The engine is started by a compressed air type starter. The overall diameter of the engine is 49.5 inches and the overall length is 55 inches. The basic dry weight of the engine is 935 pounds.

The cooling air is admitted through an adjustable shutter assembly on the front section of the engine and is exhausted through ports on both sides of the cowling. Supercharger air is admitted from the top of the cowling through a filter to the internal blower. Heated air may be selected for the blower intake from a bypass under the engine cowling.

The engine driven accessories include an air starting distributor, air compressor, propeller governor, oil pump, fuel pump, tachometer generator, generator, gun synchronizer, two magnetos, and oil scavenge pump.

A fuel shut off valve is provided to stop the supply of fuel to the engine. The valve is located in the main fuel line to the engine forward of the front spar of the wing. This valve is controlled by a lever on the left hand console in the forward and rear cockpits. See Fig 7. A hand operated fuel pump on the right side of the front cockpit is used to supply pressure to the fuel injector for starting until the engine pump takes over.

A primer pump supplies a mixture of fuel and compressed air to a 7 port manifold which is geared to the engine. This manifold is the air starter. The fuel and air mixture is then routed to the top of each cylinder for engine starting.

The engine is also supplied with oil dilution for cold weather operation.

For details of the engine breakdown and components, see Report No. TR-AG-1, "Description of Soviet ASh-21 Aircraft Engine".

B. PROPELLER, CONTROLS AND SPINNER

The propeller employed on this engine is a Vish 111 V-20 and is a two bladed aluminum, constant speed type. The overall diameter is 9.84 feet. The rotation is clockwise as viewed from the cockpit. The propeller governor is a Type R-7E, which is the latest type thus far observed. It is very similar to the constant speed governor built by Hamilton Standard. The pitch change is effected by hydraulic pressure and counterbalances. Pitch is decreased by means of oil pressure and is increased by counterbalances.

A large spinner constructed of metal is employed to cover the propeller hub and the cooling shutter assembly on the front section of the engine.

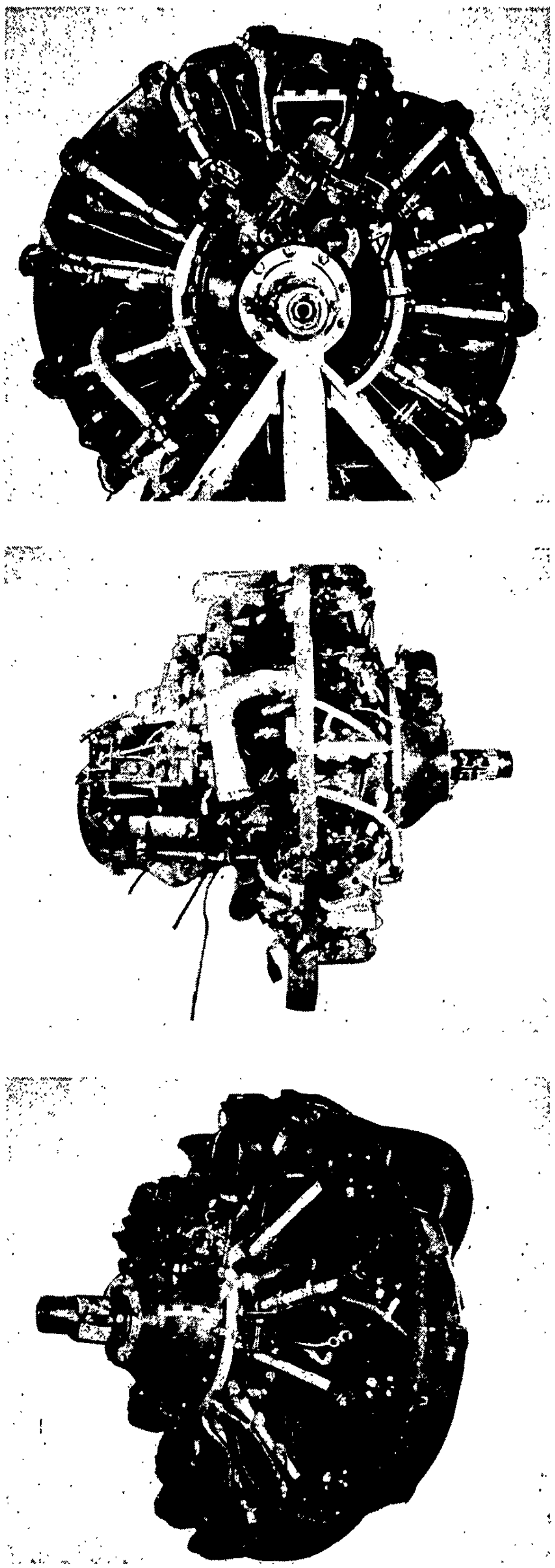

Fig. 2 ASh-21 Engine

SECTION III

AIRCRAFT SYSTEMS

A. PNEUMATIC SYSTEM

The YAK-11 employs a pneumatic system for actuating the landing gear, wing flaps, brakes, annular engine cooling shutter, engine starting, gun charging and firing. Air is supplied to the system by an engine driven compressor. Provision is also made for charging, or using, the system on the ground by utilizing an external source of air. Access to the charging connection is gained by opening a small door, located on the left side of the fuselage at the rear cockpit. See Fig 3 and 16.

The system has main and emergency air storage tanks located in the center section of the wing. The main tank, Fig 12, is mounted on the aft side, and the emergency tank, Fig 13, on the forward side, of the main wing spar. Both tanks are spherical and capable of holding a pressure of 60 atmospheres (880 PSI). The air from the engine driven compressor is first passed through a sump type filter with a drain cock and then through a screen and pad type filter. The sump filter is mounted to the right on the forward side of the firewall. The externally supplied air is passed through the same screen and pad type filter, Fig 14 and 15, as was used by the compressor air. The location of this filter is on the left side of the fuselage just forward of the ground charging filter. See Fig 15. From the pad type filter the air is supplied to the storage bottles and actuating components of the system.

The air line connecting the main storage bottle to the system goes through a main shut off valve. This valve is located on the left side of the front cockpit, and is shut off only before emergency air is used. A second air line from the main storage bottle supplies air for gun charging and firing.

The air compressor is an engine driven type mounted on the nose section of the engine. See Fig 17 and 18. It rotates at .76 of the crankshaft speed. The output of the air compressor is approximately 60 atmospheres (880 PSI). It is a two stage, two stroke compressor incorporating a tandem piston arrangement. Air is brought in through the top and is compressed in the first stage. The compressed air is then passed through a poppet valve of the larger piston, is compressed in the second stage, and discharged through the sump type filter. This compressor is very similar to the British Hayward air compressor.

The annular engine shutter is positioned by a single actuating cylinder. See Fig L. A ahrens control from the shutter to a pointer in the front cockpit on the right side above the selector valve indicates the position of the shutters.

The three selector valves, used for flaps, landing gear, and annular engine air shutter are of the cylinderical, three position type. See Fig 19 and 20.

The pressure relief valve is of very simple construction and operation. See Fig 21. The valve appears similar to a tee fitting in the line with one opening capped. This part of the tee contains a spring loaded plunger held in place by the cap nut. The valve was set to maintain a pressure of 750-800 PSI.

The landing gear actuating cylinder is mounted between an overhang at the top of the strut and one end of a bell crank. See Fig 22, 23, and 24. The bell crank acting as one half of the strut side brace scissors. See Fig 22 and 23. Retracting the actuator extends the landing gear and causes the side brace scissors to fall into a straight line. These are held in place by an internal ball lock in the actuating cylinder. Extending the actuator pushes on the top of the strut and causes the side brace to pivot and fold, retracting the strut. An uplock holds the landing gear in a retracted position. An air operated plunger in the uplock releases the landing gear when it is to be extended. The uplock may also be released by a pull cable from the front cockpit for emergency operation.

The landing flaps are pneumatically operated by a double ended actuating cylinder, push pull rods and linkage. See Fig 25. Each flap is locked in the up position by five spring loaded mechanical locks. See Fig 26. The actuating cylinder is located at the center line of the airplane under the rear cockpit floor. The most important design feature is the flap up lock incorporated in the system. The release of the flap uplock is accomplished by the initial travel of the flap actuating linkage in flaps down motion. Five bell cranks spaced along the span of the flap, link the flap push pull tube with the flap up lock. The flaps are locked automatically when fully raised. The locks are spring loaded in the closed position. The remaining travel of the tube lowers the flap.

The wheel brakes are pneumatically operated through a differential and bleed valve mounted under the rear cockpit floor. See Fig 27, 28, 29 and 30. The primary pressure supplied through a bleed valve to the differential valve is controlled by the manually operated levers on the front and rear control columns. See Fig 31 and 32. The differential valve control is linked to the rudder bar, and its function is to relieve the pressure from the brake line on the side of the airplane opposite the direction of the turn and to supply air to the wheel being braked. With the rudder bar in neutral, both brakes are under equal pressure. The pressure is controlled by the manual lever on the control column which actuates the bleed valve. Upon releasing of the brake lever the brake pressure is bled through the bleed valve into the atmosphere. This aircraft is not equipped with a parking brake.

An additional safety feature is incorporated on the aircraft for the instructors use to prevent ground looping and taxing accidents. A brake emergency button is housed in the top of the grip on the rear control column between the brake metering and bleed valve to release air from the brakes or prevent air from going to them. See Fig 32. When the instructor depresses the button, the pressure is relieved through slots around the button. See Fig 32, 33, 34 and 35.

The brakes used on this aircraft are the single acting, two shoe, type. See Fig 36, 37, 38 and 39. This type of brake is similar to that used in U. S. light aircraft. When air pressure is applied to the piston at the top of the brake housing, it forces the shoe about a pivot against the drum. The same action takes place simultaneously with the other shoe in the same brake.

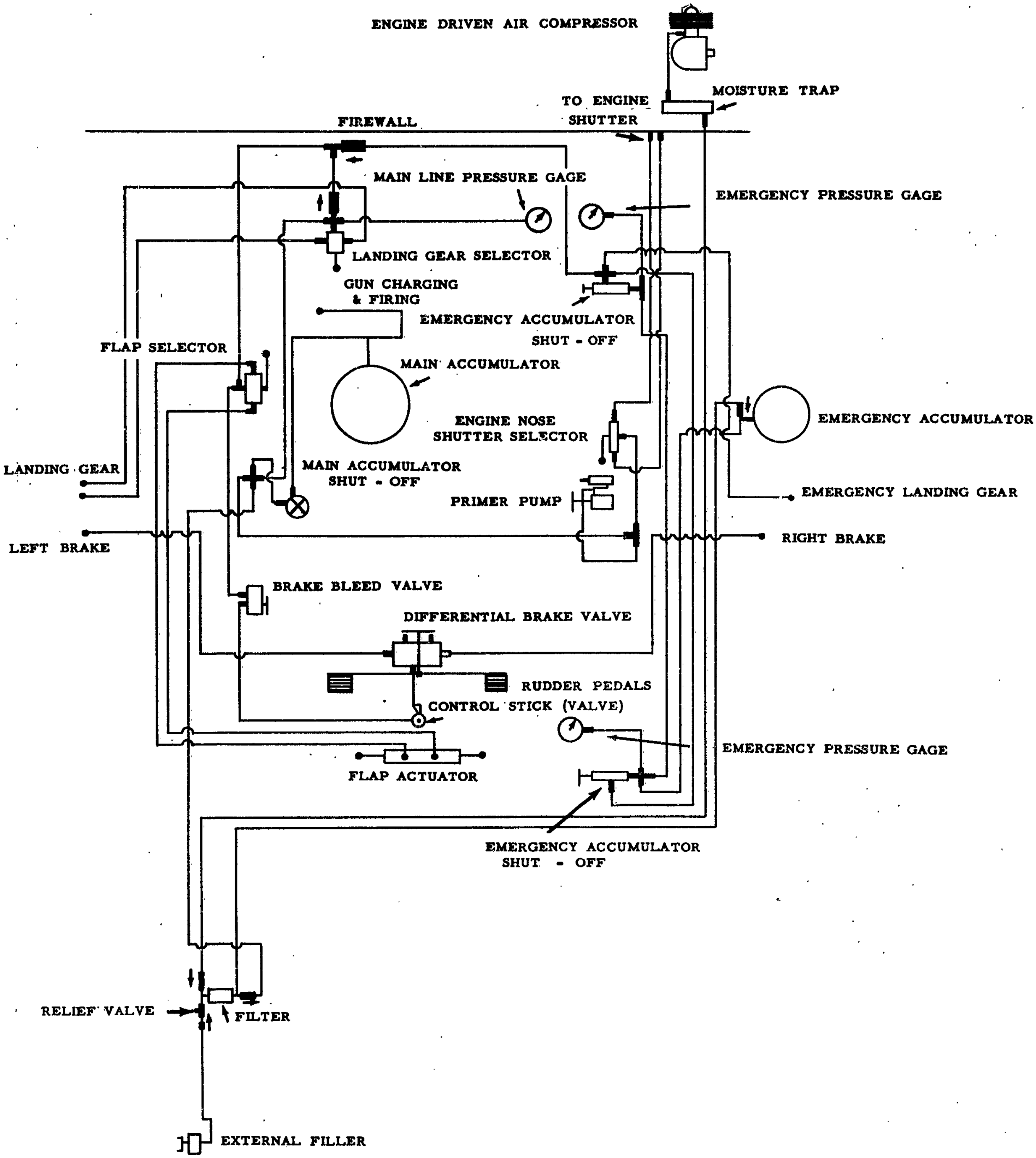

Fig. 3 Pneumatic System

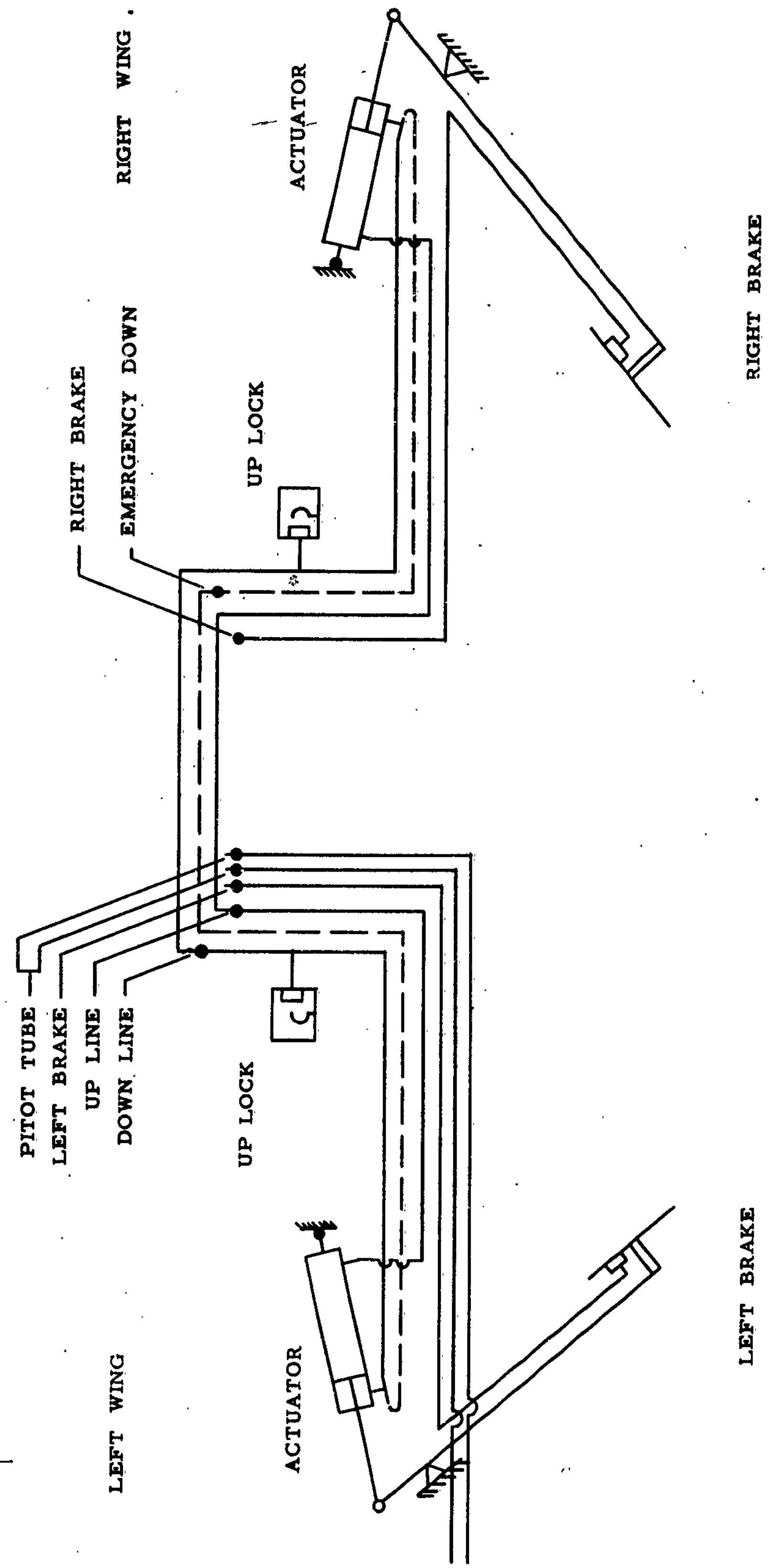

Fig. 4 Landing Gear System

B. FUEL SYSTEM

The YAK-11 fuel system is shown in figure 5. The main components of the system are engine driven fuel injector, three fuel tanks, wobble pump, priming pump, engine driven fuel pump, and two screens.

The engine driven fuel injector receives strained gasoline from the sump tank and is supplied under pressure by the engine driven fuel pump or the wobble pump.

There are two main fuel tanks which are located in the inboard section of each wing, between the front and rear spars. These metal tanks are the riveted type. No provision is provided for self-sealing. Each main tank has a capacity of 173 liters. The filler neck of each wing tank houses a mesh brass filter under the filler cap. The fuel gauges are located in the upper surfaces of each main tank. An access door on the upper surface of the wing is opened for servicing with fuel. The gauges are the mechanical float type and transmit an electric signal to the cockpit fuel gauge. Between the main tanks is a sump tank which is fed from the main tanks by gravity. The capacity of this tank is 13.5 liters. From the sump tank fuel flows through the main fuel line to the engine driven fuel pump to the engine driven fuel injector. There is a check valve in the main fuel line to the engine from the sump tank. This check valve prevents reverse fuel flow and allows initial fuel pressure to be built up by the use of the wobble pump. There is a flapper valve in each line leading to the sump tank. See Fig 40. The purpose of the valve is to prevent fuel from draining out of one wing tank into the other during maneuvers.

The three fuel tanks are commonly vented to the atmosphere. In inverted flight for short durations the sump tank is fed fuel through the vent lines of the wing tanks. In normal flight the vent lines connect to the top of each tank.

A primer pump is used to inject fuel into the air starting line for initial fuel supply when starting the engine. See Fig 41. The priming pump also contains the air supply valve for starting air.

The wobble pump is a double acting, constant flow, vane type pump. See Fig 42. The pump is similar to the type used in U. S. light aircraft. The operation of the wobble pump can be operated only from the front cockpit. On the intake stroke fuel is taken into the chamber. The flapper valve on the exhaust port is closed. On the return stroke the fuel is discharged under pressure. The same action occurs in the second chamber. When one chamber is intaking fuel the other chamber is exhausting fuel which provides a constant flow of fuel under pressure. This pump has fewer moving parts than the U. S. type of wobble pump.

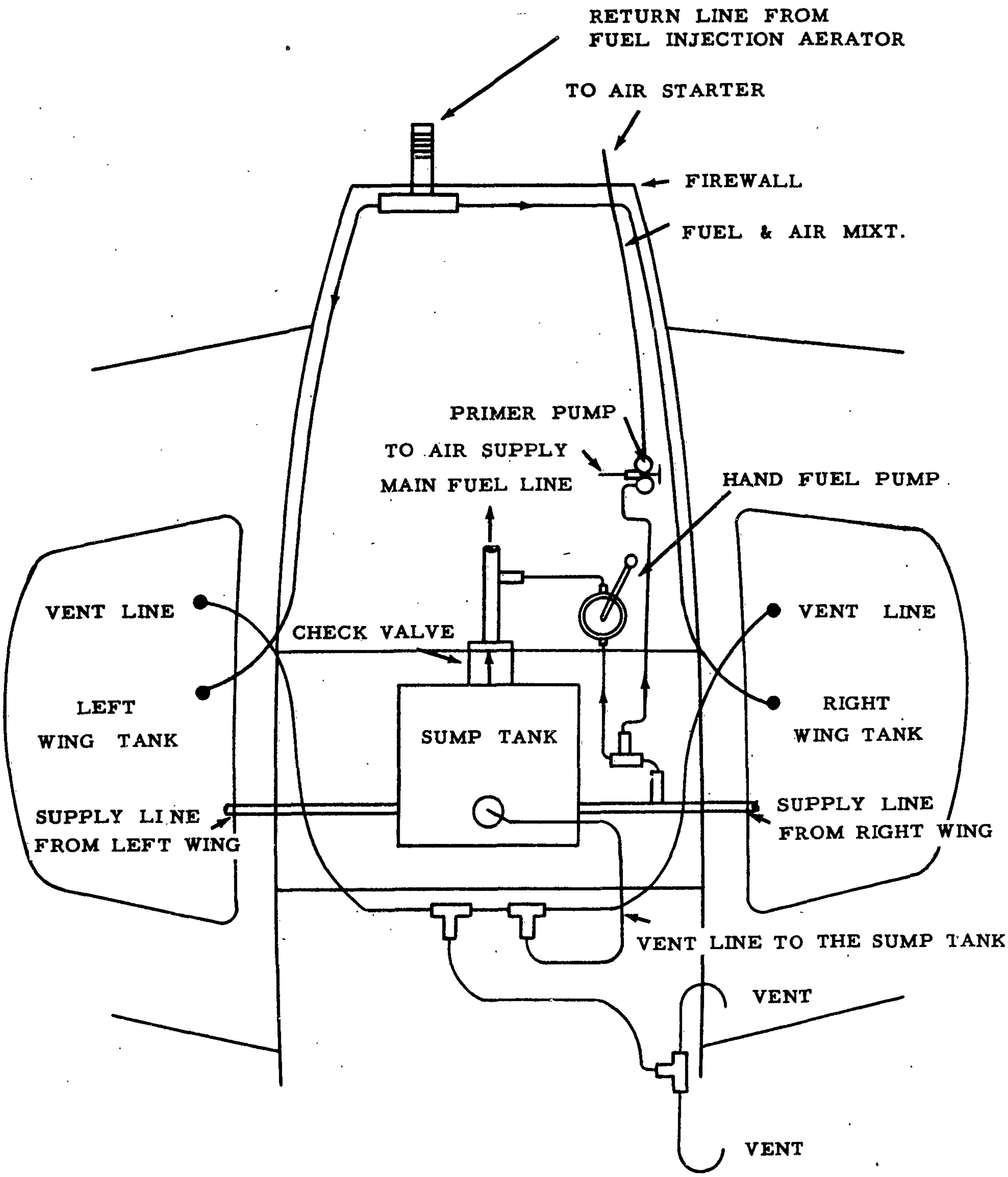

Fig. 5 Fuel System

C. ELECTRICAL SYSTEM

A 24 volt direct current electrical system is used in the YAK-11. The requirements imposed upon the system are very small in comparison to USAF requirements due to the extensive use of pneumatics in this aircraft.

A type 12A-10 battery is installed on a shelf below the radio equipment aft of the rear seat. The designation of this battery indicates that it is a 12 cell lead acid aircraft battery with a rated capacity of only 10 ampere hours. An external power source can be connected to the aircraft by simply removing the two prong connector from the outlet located on the battery case and connecting it to the lead from the external power source.

A single engine driven generator, type GSK-1500, mounted on the rear accessory section of the ASh-21 engine delivers 1500 watts of direct current power at 27.5 volts. See Fig 43. Earlier models of the YAK-11 were equipped with 500 watt generators. The use of inverters for supplying alternating current to gyro flight instruments imposes an additional power requirement on the later models. Formerly, these instruments were vacuum driven. Components were found which indicated that an installation of a more complex gun-sight was installed. This would also impose additional electrical power requirements.

A conventional vibrator type voltage regulator maintains the generator voltage between 26.5 and 28.5 volts. A current limiter element controls the maximum load current of the generator to 50 amperes under overload conditions.

To reduce interference to radio reception and to communication devices, a type SF-1A filter is installed between the voltage regulator and the main distribution panel.

A type PAG-10 inverter supplies a 36 volt, 400 cycle, 3-phase output voltage to the gyro flight instruments, but not to the radio compass as is done in USAF radio compass equipment. The inverter is mounted on rubber shock absorbers and is attached to the top of the left wing, just inside the fairing. The inverter appears to be a simplified copy of the World War II German inverters. No means of regulating the frequency or output voltage are provided. However, the inverter supplies a constant load and, under this condition, the added expense of a regulating device is unnecessary. Results of a complete analysis of this inverter are available.

The magneto selector switches are wired so as to give the instructor in the rear seat master control at all times. Two toggle switches are installed to the right of the magneto selector switch in the rear cockpit. Placing these in the "up" position and turning the rear cockpit selector switch to the 1 ↑ 2 position will give control to the front cockpit. The instructor could cut the front cockpit magneto selector switch out of the circuit at any time by placing the toggle switches in the down or "off" position. See Fig 6.

Two fluorescent fixtures for instrument lighting and one map reading fixture are identical to types used in current USAF aircraft.

A 24 volt, 220 watt bulb is used in the single landing light. Tests of wattage required for safe flare-outs and landings in a comparable USAF airplane indicated that such a lamp will provide inadequate illumination for satisfactory operation.

Conventional wiring and electrical connections are used throughout the YAK-11.

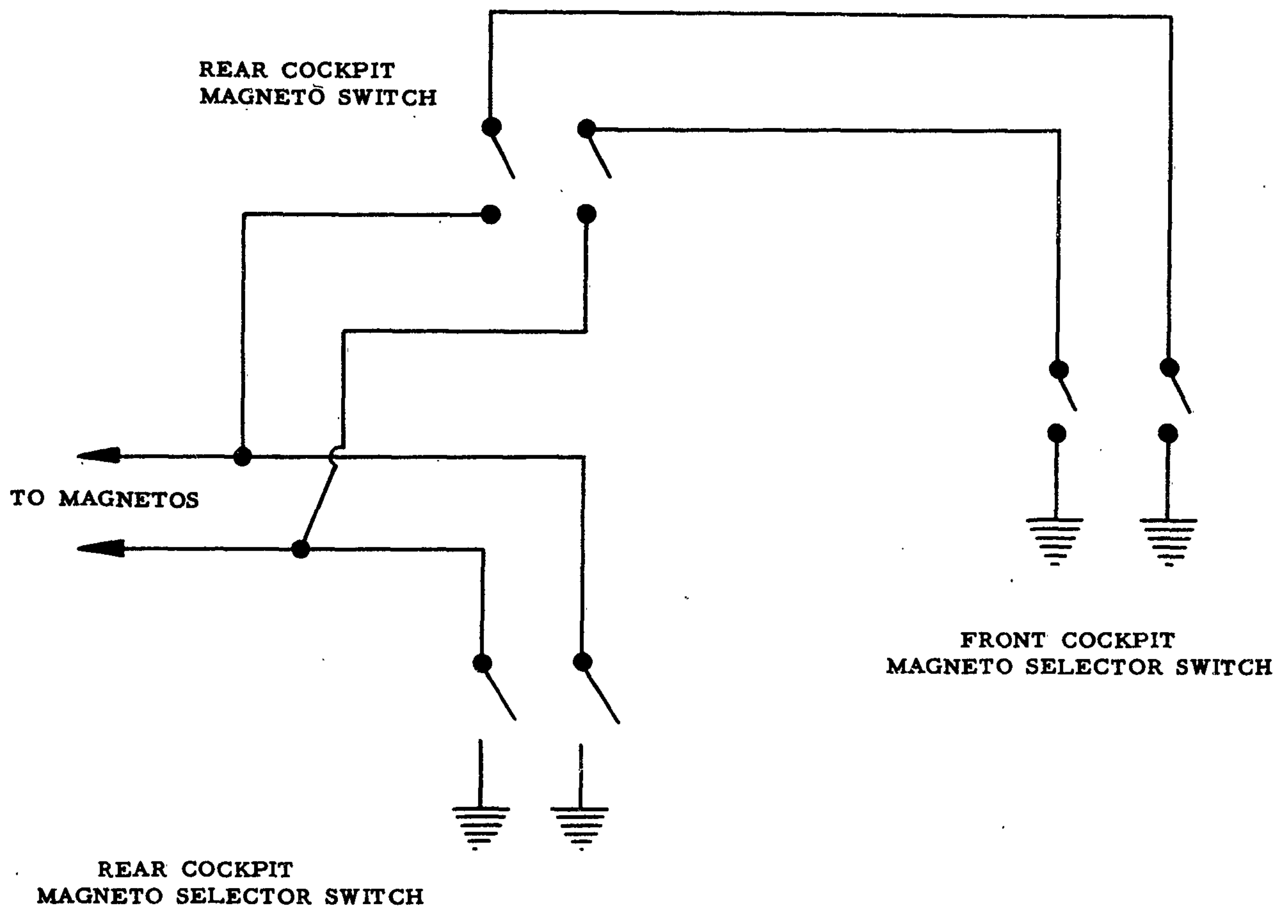

Fig. 6 Magneto Switch Wiring Diagram

D. COCKPIT ARRANGEMENT AND INSTRUMENTS

The cockpit arrangements are simple, compact and designed to meet the basic requirements of a fighter trainer. See Fig 45 and 46.

The quality and arrangement of the instruments, controls, lights, etc., with the exception of the rearrangement of some of the instruments in the center and right hand instrument panels, are the same as found in the earlier produced models of this airplane. The center instrument panels contain three rows of three instruments each. In the front cockpit the instruments are arranged, from left to right, as follows: in the top row are the altimeter, a blank area used by the gun sight, and the remote compass indicator; in the center row are the airspeed indicator, combination flight gyro and turn and bank indicator, and the rate of climb indicator; in the bottom row are the manifold pressure gage, tachometer indicator, and the engine gage unit. A radio beacon indicator is mounted in an extension of the lower right hand side of the center panel. See Fig 7. In the right hand panel, the flight indicator and camera gun frame counter have been removed and the emergency air pressure gage and pneumatic system pressure gage installed in their place. A clock has been added to the upper left hand corner of the panel. Two indicating lights are installed to replace the camera gun frame counter.

In the aft cockpit the instruments are arranged in the center instrument panel from left to right as follows: in the top row are the airspeed indicator, a combination gyro flight indicator and turn and bank indicator, and a rate of climb indicator; in the center row are the altimeter, remote compass indicator, and the clock; in the bottom row are the manifold pressure gage, tachometer indicator, and the engine gage unit. The flight indicator has been removed from the right hand instrument panel and placed in the center panel.

The only outstanding change in the instruments is the relocation of the gyro flight indicator to the center of the instrument panel, the conversion of the flight indicator from a vacuum driven to an electrically driven instrument, and the combining of the turn and bank indicator and artificial horizon into one compact instrument. An inverter was provided to supply power for this instrument. The inverter is mounted on the upper surface of the left wing beneath the wing fairing.

The Soviet flight indicator presentation of a fixed horizon with a movable aircraft differs from the current USAF flight indicator presentation of an immobile aircraft with a moving horizon. In the Soviet indicator the model aircraft is displaced in exactly the same manner as the actual aircraft with respect to the natural horizon. For example, during a dive the model drops below the horizon to indicate the relative pitch attitude while indicating the pitch attitude in degrees on a scale on the center of the indicator. The instrument will indicate a climb or dive to approximately 80° and the angle of bank accurately to approximately 60°. Pitch attitude changes through 360° can be accomplished without upsetting the gyro.

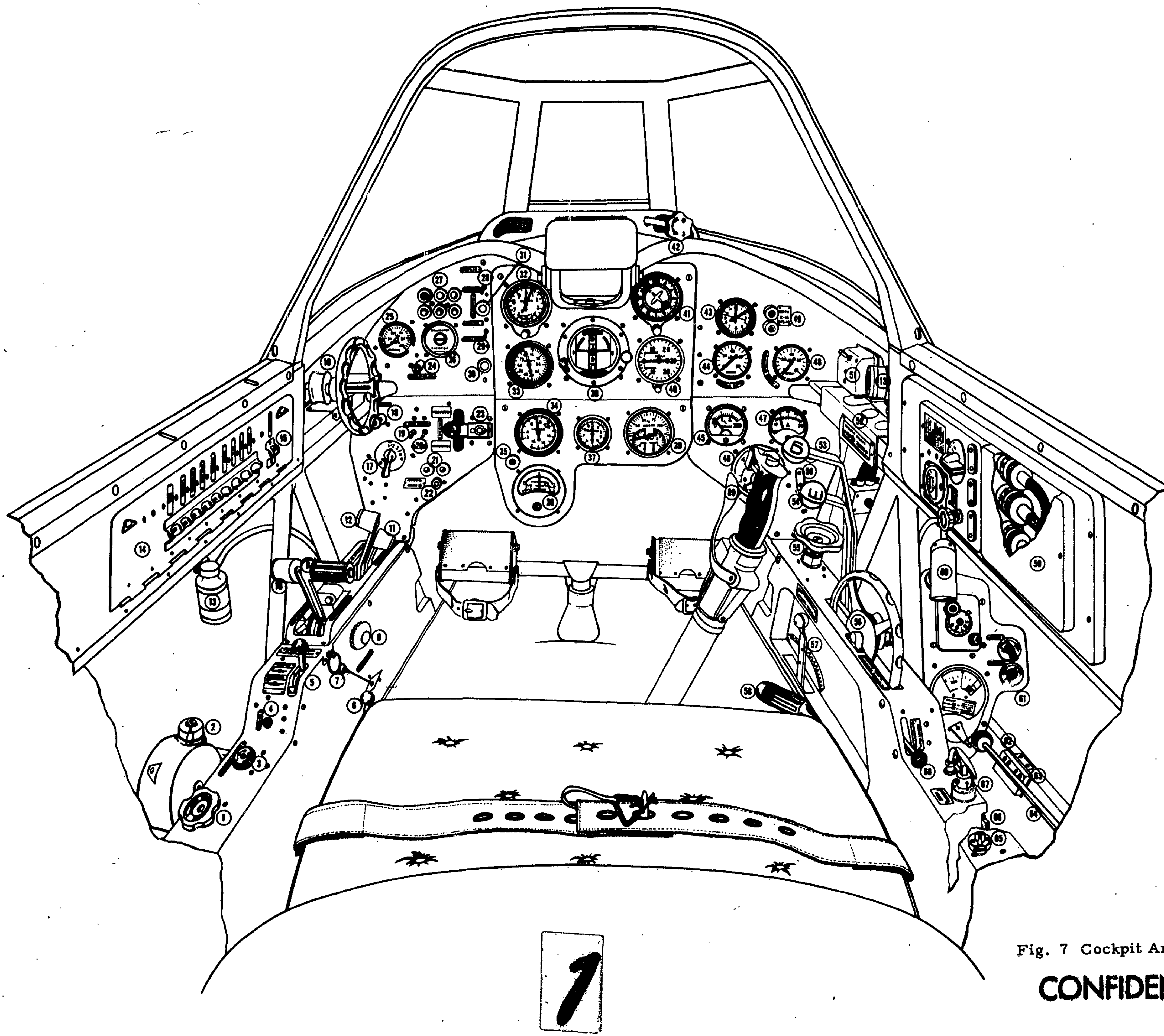

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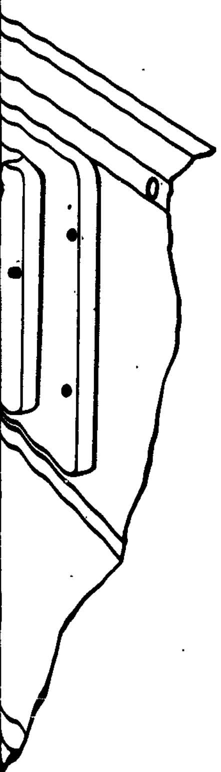
Fig. 7 Cockpit Arrangem



1. Normal pneumatic system valve
2. Oxygen control "on/off"
3. Oxygen outlet valve
4. Radio Compass loop switch
5. Flap control (up, neutral, and 45° positions)
6. Control for moving seat forward or rearward
7. Camera hatch cable
8. Friction lock
9. Throttle
10. Propeller control
11. Lever for stopping engine
12. Fuel shut off (emergency use)
13. Fluorescent lamp fixture
14. Electric panel
15. Battery switch
16. Elevator trim control
17. Magneto switch
18. Starting booster coil button
19. Navigation light switch
20. Landing light switch
21. Landing gear warning lights (on when gear is down)
22. Switch for checking operation of landing gear warning lights
23. Landing gear extension and retraction control
24. Gun charger switch
25. Oxygen pressure gauge
26. Oxygen flow indicator
27. Code lights (for use between cockpits)
28. Bomb "armed-safe" switch
29. Bomb selector switch (up for left only, down for both)
30. Bomb away light
31. Bomb "armed-safe" light
32. Altimeter
33. Air speed indicator
34. Manifold pressure gauge
35. Radio compass "on" light
36. Radio compass or course indicator
37. Tachometer
38. Artificial horizon
39. Oil temperature and fuel and oil pressure gauge
40. Rate of climb indicator
41. Remote compass indicator
42. Ventilator control
43. Clock
44. Normal pneumatic system pressure gauge
45. Cylinder head temperature gauge
46. Fuel quantity gauge
47. Combination volt-ammeter
48. Emergency pneumatic system pressure gauge
49. Gun camera lights
50. Fuel gauge tank selector switch
51. Transmitter off-on switch
52. Engine cooling shutter position indicator
53. Emergency bomb release
54. Emergency landing gear up-lock release
55. Emergency pneumatic system valve
56. Cowl flap control
57. Oil cooler shutter control
58. Handle for moving seat up and down
59. Radio compass control panel
60. Cockpit light fixture
61. Radio
62. Headphone jack box
63. Microphone jack box
64. Wobble pump
65. Oil dilution switch
66. Starting air valve
67. Primer
68. Engine cooling shutter control (up to open)
69. Brake lever

7 Cockpit Arrangement

SECTION IV

ARMAMENT

A. WEAPON INSTALLATION

Although a gun was not mounted on the aircraft, previous intelligence information, as well as the accessories which were mounted on the aircraft, confirm the installation of a single, fixed, forward firing 12.7mm Berezina machine gun which is synchronized to fire through the propeller arc.

The 12.7mm Berezina UBS, which is the synchronized weapon, is a gas operated, air-cooled, belt fed aircraft machine gun of World War II vintage. The feed takes place from the right hand side of the gun and is not interchangeable. It is, however, orthodox in that it utilizes a disintegrating metal linked belt. The metal links contrary to common practice with a right hand feed, fall away downward and to the right of the gun. The cartridge cases follow the more normal practice of ejection from the left side of the gun.

Charging of the gun is normally accomplished by air pressure, however a manually operated pull cable is used in the event of a loss of air pressure. The air pressure (approximately 375 PSI) required for operation is supplied by the aircraft pneumatic system. The air is stored in an a storage bottle under approximately 60 atmospheres of pressure and by means of a regulator the pressure is reduced to approximately 24 atmospheres of pressure before reaching the gun charger.

Immediately ahead of the fire wall, there is a gun deck which is a part of the aircraft structure. The gun in mounted on the deck at the left of the aircraft's center-line. The deck also serves as a mount for the ammunition can, the case and link chutes, the gun mounts, the charging valve, and the firing solenoid. The rear gun support consists of a steel bracket and plate arranged to provide lateral movement by means of a pair of threaded studs. This movement would permit azimuth adjustment during harmonization. The forward portion of the gun is supported by two spring loaded trunnions which are attached to the forward end of the receiver. An adjustable post type mount is attached to the trunnions for the vertical movement required for harmonization.

The ammunition can which has the overall dimensions of 15 x 12 x 6 inches is a riveted aluminum alloy assembly employing an integral feed chute. It is located approximately on the center-line of the aircraft and is connected directly to the feedway of the gun by a short section of chuting. The can is held securely in place by four plunger type latches. The estimated capacity of the box is 100 linked rounds. The can cover and upper portion of the feed chute are individually hinged and may be opened for loading by depressing a plunger type latch. Ejected links and cases pass through separate openings in the gun deck and fall into a common container which is part of the airframe structure. Access to the container is gained by opening the forward fuselage hinged panel on the left side of the aircraft.

pivoted wiper arm which moves across a curved plate that is divided into five segments. A voltage value, which is proportional to five increments of barometric pressure, is obtained by this action.

As for mounting a sight the size of the K-14 it does not appear that there is sufficient space judging from the sight head mounting bracket. It is, therefore, assumed that some modifications have been made. For training purposes a straight reflex sight could have been mounted, however, this installation would render the input data units unnecessary.

C. BOMBING EQUIPMENT

The bomb suspension hooks and electrical arming mechanism appear to be identical to the "Bomb Rack, External, BD2-45" as shown on page 1-9-E-5 of the Characteristics and Performance Handbook, Foreign Aircraft Armament. It has a maximum capacity of 100 Kg (220 lbs).

A streamlined fairing is secured to, and incloses, the suspension assembly. Both are attached to the underside of the wing by four bolts, two at either end. Cross beams are secured to front and rear of the shackle to provide sway bracing, which is made up of threaded bolts and jam nuts.

When the bomb release solenoid is energized, its plunger frees a linkage which is under spring tension. Movement of the linkages releases the trigger arm from engagement with the carrying hook and the bomb is free to fall.

The arming mechanism is attached to the rear section of the shackle and is made up of a solenoid plunger with a rounded end which in the extended position contacts a stationary rounded stud. The solenoid plunger is held in the extended position by a spring which maintains sufficient tension to retain the arming wire during flight and yet release the wire in the event it is desired to drop the bombs "safe". When the arming wire solenoid is energized the two plungers are held together and retain the arming wire which permits an "armed" release of the bomb.

D. CAMERA

Provisions for the installation of cameras in three positions were noted during inspection of the aircraft. Primary location of the gun camera appears to be in the leading edge of the right wing, with an alternate position on top of the windscreen directly above the gun sight mount bracket. The latter position may possibly be used for a camera which would record the target and the reticle image at the same time. Support brackets for a third camera installation were located at the bottom of the fuselage, aft and to the left of the rear cockpit under the communications equipment shelf. This installation may be for a camera to be used in bomb scoring during training or reconnaissance. A sliding door, spring loaded in the closed position, was directly below the mounting brackets and could be manually operated from the front cockpit by means of a pull cable. Each of the three camera positions were provided with mounting brackets and electrical connections.

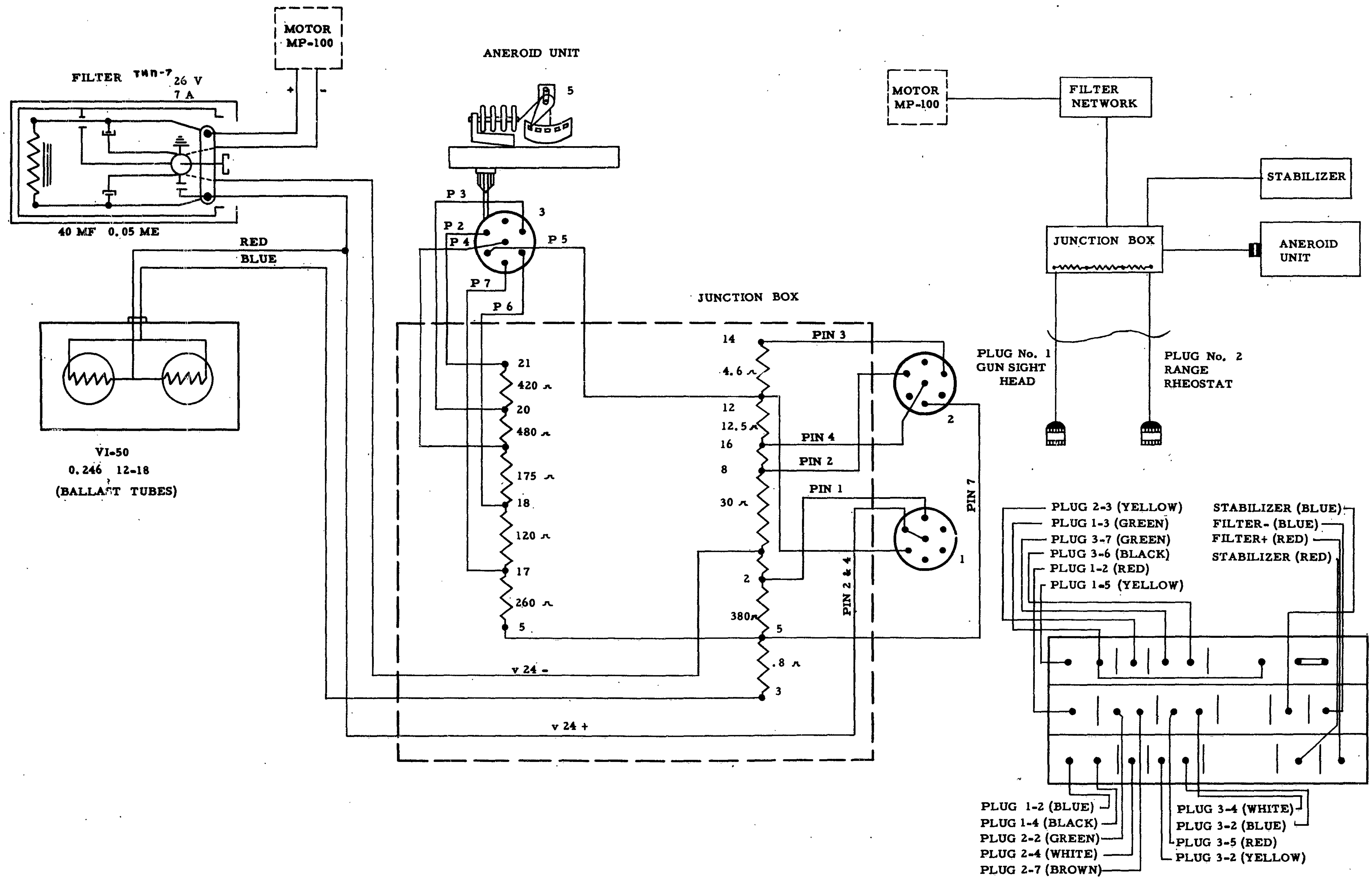


Fig. 8 Gun Firing System

SECTION V

ELECTRONICS EQUIPMENT

The electronics equipment installed in the YAK-11 consisted of communications, navigation, and intercommunications equipment. The installation is believed to be a typical example of the electronics equipment in late model Soviet fighter and trainer type aircraft except for some variation in the location of major components and controls and the possible addition of IFF or radio altimeter units.

All of the installed equipment has been previously reported; however, the HF transmitter, the iron core compass loop, and a late model intercommunications amplifier were not previously available for complete analysis. These units will be the subject of individual electronic reports following their detailed study. Complete information on the other units which have been previously reported can be found in reports referenced herein.

Specifically, the following electronic equipment was installed in the YAK-11:

Communications Equipment

1. High Frequency Receiver, Soviet Type RSI-6M-1 (3.75-5.00 Mc), Serial No. 17667, date of manufacture: March 1950.
2. High Frequency Transmitter, Soviet Type RSI-6K (3.75-5.00 Mc), Serial No. 20222, date of manufacture: December 1949.
3. Transmitter Dynamotor, Soviet Type RU-45-A, Serial No. E01114.
4. Interphone Amplifier, Soviet Type SPU-2M-bis, Serial No. B 19776.
5. Interphone Dynamotor, Soviet Type RU-11AM, Serial No. E015148.

Navigation Equipment

1. Radio Compass Receiver, Soviet Type RPKO-10M (270-730 Kc), Serial No. 0.1511, date of manufacture: April 1950.
2. Compass Receiver Dynamotor, Soviet Type RU-11AM, Serial No. E 847574.

Antennas

A double strand wire type antenna extending from a mast at the rear of the cockpit to the top of the vertical stabilizer was used as a receiving antenna for the HF receiver and a sense antenna for the compass receiver. The above wire also serves as the transmitting antenna for the HF transmitter.

An iron core stationary loop antenna, flush mounted in the top of the fuselage behind the cockpit canopy, was used in conjunction with the RPKO-10M navigation receiver.

A. COMMUNICATION AND NAVIGATION EQUIPMENT

The Soviet Type RSI-6M-1 radio receiver is described in detail in ATIC Study No. 102-EL8/51-34. It is an 8-tube superheterodyne receiver with excellent stability characteristics. Reception is limited to phone or modulated radio telegraph signals. The unit installed in the YAK-11 was identical to the latest types previously analyzed, and except for some variation in inspection stamp numbers, no significant difference was noted when this unit was compared to Receiver Serial No. 17166 which was obtained in Korea.

The Soviet Type RSI-6K transmitter is the first unit known to be available for detailed analysis. It operates essentially as either a self excited amplitude modulated oscillator or as a crystal controlled amplitude modulated oscillator using a type 6L6 tube. It is capable of voice transmission with a power output of approximately 6 watts. Complete details on this type transmitter are given in ATIC Technical Report No. TR-EL-44. No operating crystal was found with the equipment. The RSI-6K is a modification of the earlier RSI-6 transmitter. An extra tube which acts as a modulated crystal oscillator has been added to permit operation on one crystal controlled channel. In addition, a meter has been placed in the front panel to indicate radio frequency current in the antenna. This represents an improvement over the small light bulb tuning indicator used in the RSI-6.

The Soviet Type SPU-2M-bis intercommunications equipment consists of a one tube (type 6F6) audio amplifier. This unit has been modified considerably from the previously reported SPU-2M model. Major changes include the use of late type components, such as cased transformers with humidity glass to metal seals, sealed capacitors, and carbon deposited resistors. The binding post connector strip on the front panel has been replaced with a quick disconnect type cable receptacle. A complete analysis of this unit is contemplated.

The RPKO-10M is a homing receiver which has been described in detail in ATI Study No. 102-EL-17/51-34.

It is used in conjunction with a fixed, iron core, flush mounted loop type antenna. The dynamotor power supplies have also been completely analyzed and the information on both the Type RU-45-A and the Type RU-11AM is given in the above referenced reports.

B. COMMUNICATION AND NAVIGATION EQUIPMENT CONTROLS

Figure 10 is a pictorial drawing showing the location of the electronics equipment in the YAK-11. A block diagram of the interconnecting cables and controls is given in Figure 9.

The high frequency transmitter is controlled by a press-to-talk switch on the pilot's (forward cockpit) throttle or on the rear cockpit throttle. The frequency of the set is not easily changed during flight and therefore the pilot must rely on one channel for transmission.

The high frequency receiver is tunable by a remote mechanical tuning knob located on a panel to the right of the pilot's right knee. Any frequency in the 3.75 to 5 megacycle range may be selected in flight.

The frequency of the navigation receiver is changed by a remote tuner located on the same panel as the high frequency receiver tuning knob. The navigation receiver is switched in for use as a radio compass or as a conventional low frequency superheterodyne receiver by a switch in the control box located above the remote tuning control below the canopy guide rails in the forward cockpit. This control box also controls the use of the RSI-6 equipment. The left-right indicator for the compass is located on the instrument panel.

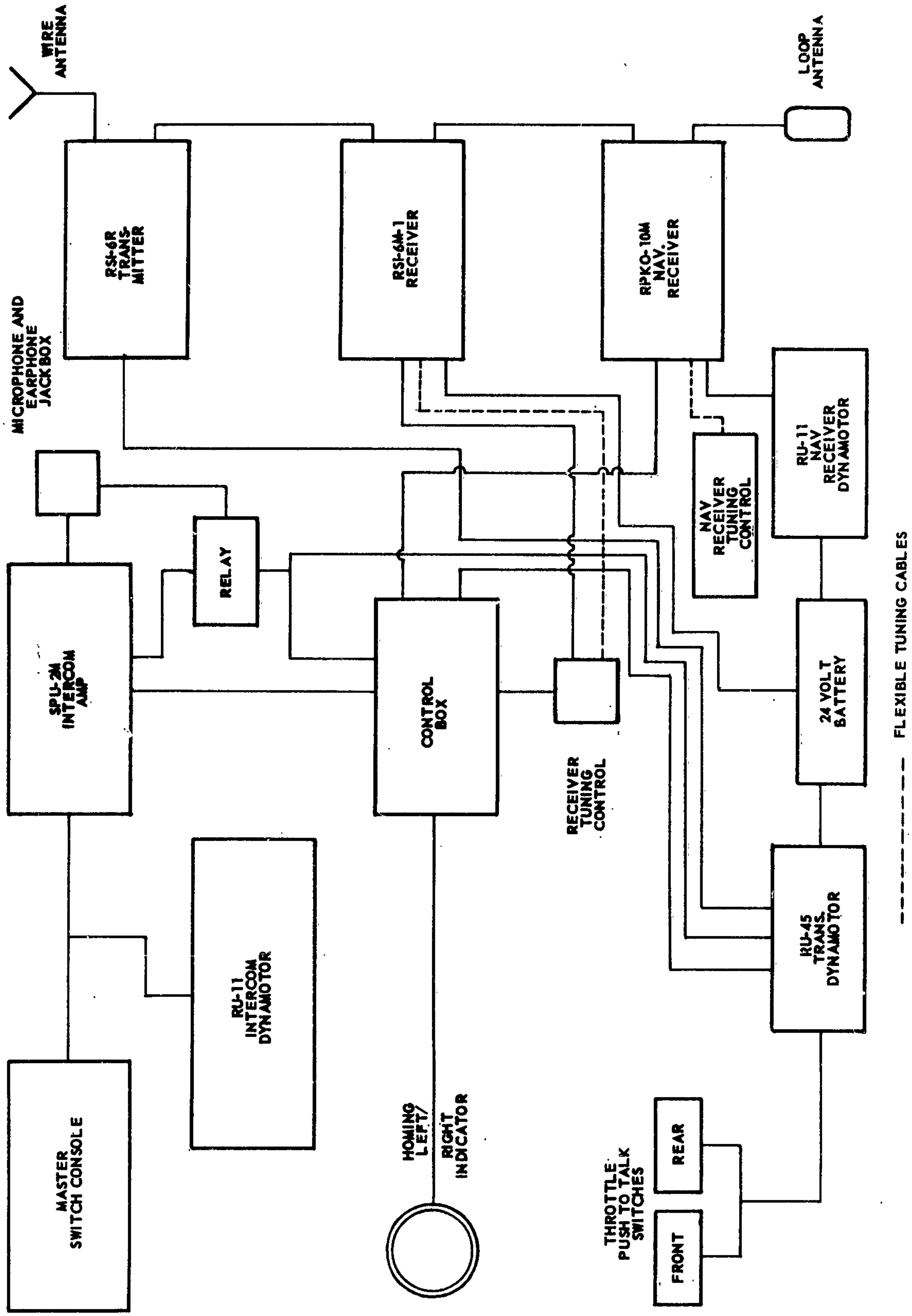


Fig. 9 Yak-11 Communication and Navigation System - Block Diagram

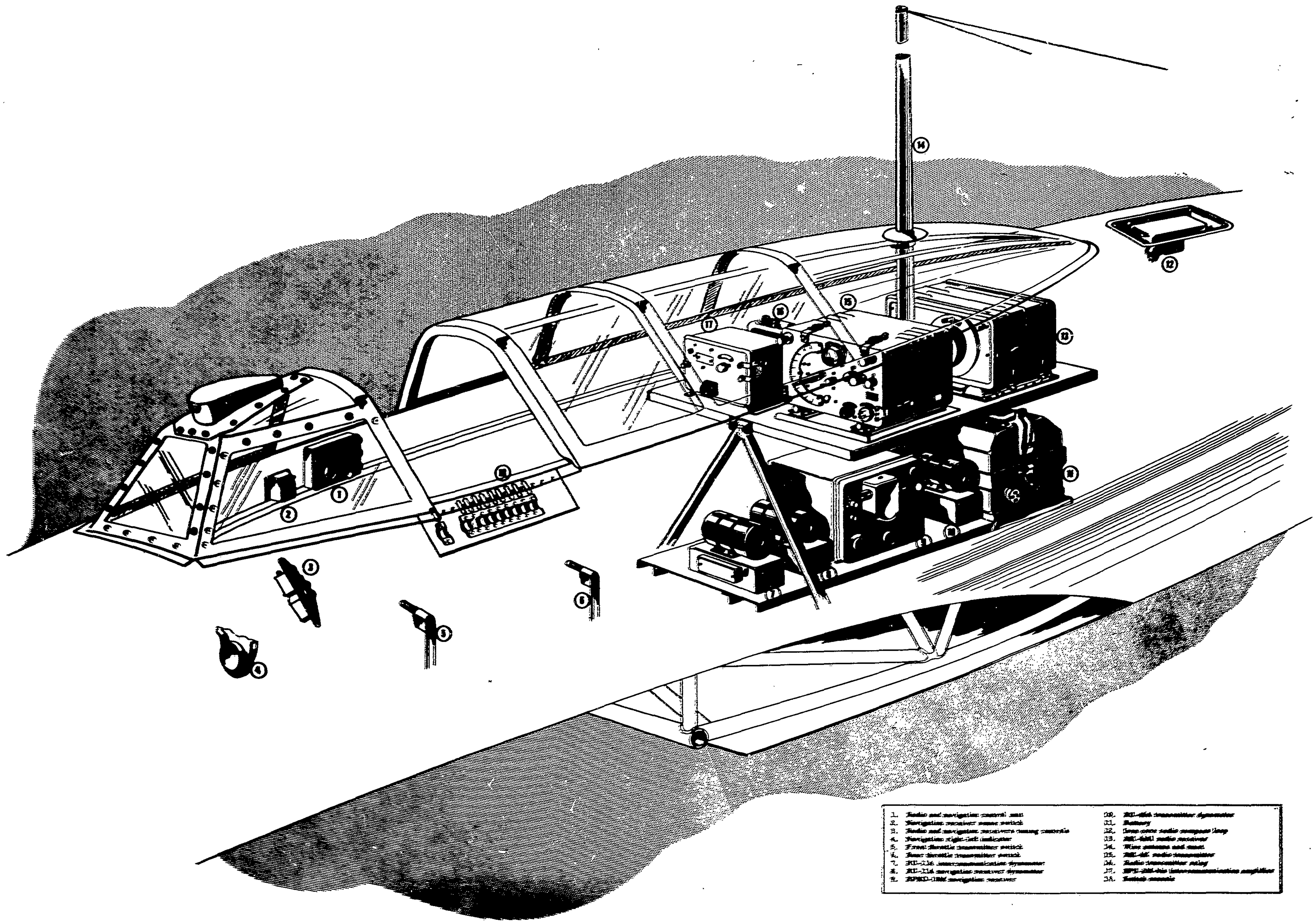


Fig. 10 Electronic Installation

SECTION VI

MATERIALS

Airframe parts for materials examination were selected from what were considered to be the most critical applications. The analysis of metal, plastic, and rubber parts include type and quality, comparison to U. S. materials for the same application and, where possible, the effect of the type and quality of the material on aircraft performance.

A. METALS

Aluminum, steel and stainless steel parts selected for this analysis are considered to be the highest stressed components, requiring the best quality.

The landing gear strut and selected parts of the ASh-21 engine are being examined metallurgically and will be reported in a subsequent ATIC study.

A YAK-11 engine mount had been examined prior to the one from the complete airframe. The date of manufacture of the first engine mount is unknown; its date of acquisition is close to the date of acquisition of the complete airframe.

1. Aluminum Parts (Table 3)

a. Sheet Materials (Figs 47, 48 and 49)

All of the sheet materials examined were of the alclad type. The aluminum coatings ranged from 3 to 5% per side of the total sheet thickness, this is comparable to U. S. practice. The alloy used for the core was the Soviet D1 type which is equivalent to 17s. The previously examined IL-10 airframe also used 17s skin. A considerable amount of 17s sheet was shipped to the Soviets on lend-lease during World War II; 24s was probably not easily available to the Soviets at the time the airplane was designed. Therefore, they apparently adopted 17s for skin on the engine fighters. Little weight saving could be effected by the substitution of 24s.

In general, the 17s sheet specimen were fine-grained, good quality materials with normal solution heat-treated structures. Two exceptions were noted in the thinnest sheet. In both of these cases, an excessive time at the solution heat-treating temperature had caused diffusion of copper from the core to penetrate the cladding completely. Diffusion in Soviet alclad aircraft skins has been noted before, but not to this extent. The resistance to corrosion of these materials would be inferior to that of properly heat-treated sheet.

The sheet materials were all anodized and chromate sealed. Unexposed surfaces were further protected with a zinc chromate-type primer. Exposed surfaces were primed with zinc chromate, painted with an intermediate coat of aluminum-pigmented vehicle, and finished with a gray lacquer.

b. Extrusions (Fig 47)

The stringer is an extruded bulb angle made from the Soviet D1 alloy. The stringer had been anodized and chromate sealed and was painted with zinc chromate-type primer. The grain size was extremely coarse, but the sample otherwise had a normal heat-treated structure. The magnesium content was higher by 0.16 percent than the upper limit (0.4-0.8% Mg) permitted by the Soviet specifications for alloy D1 (17s). However, this would not have a deleterious effect on the mechanical properties of the material.

c. Rivets (Fig 48)

The rivets, taken from the built-up spar cap, were identified as the Soviet D18 alloy. This is equivalent to the U. S. alloy A17S, which is used in U.S. practice for similar applications.

d. Forgings (Figs 47 and 50)

The forgings were identified as the Soviet AK6 alloy. The aileron control support carried the marking "AK6". These forgings were all anodized and chromate sealed. This alloy has no U. S. equivalent, but the closest U. S. alloy is 14S. AK6 forgings are used in the solution heat-treated and artificially aged condition in Soviet practice. In this temper, the alloy develops strengths that are somewhat higher than those of 17S-T4; however, higher strengths than in AK6 are obtained in the artificially aged 14S alloy, which is used in the U. S. in forgings for similar applications. A comparison of the mechanical properties of these alloys is given in Table 1.

Grain size in these forgings showed wide variations, ranging from fine to coarse in the aileron control support, from fine to medium in the bracket, and from medium to coarse in the landing gear support. The parts otherwise had normal heat-treated structures. The Brinell hardness (500-kg. load-10 mm. ball) on two of the three forgings was 107 and 117, respectively.

2. Steel Parts (Table 4)

a. Plain Carbon Steel (Fig 52)

Among the parts examined Soviet steels 20, 35, and 50 (U. S. equivalents AISI 1020, 1030, and 1050) were used for a flange, a washer, and several nuts. The metallurgical quality of the parts was satisfactory. The nut and bolt of the first engine mount examined were cadmium plated, the nut and bolt of the second engine mount were zinc plated. Cadmium plating gives better corrosion protection than zinc plating. No conclusions can be drawn as to the purpose of the change since the relative dates of manufacture of the two engine mounts are unknown.

b. Low Alloy Steels (Figs 50, 51 and 52)

All the low alloy steel samples found in the airframe were of the 1% chromium, 1% manganese, and 1% silicon type varying only in carbon content from 0.20% to 0.35%. Selected YAK-11 components made of this steel were found to be structural tubing for the fuselage and engine mount as well as highly stressed nuts and bolts. It is significant to note that for low alloy steel applications in Soviet airframes this type of steel is used almost exclusively. Highly stressed steel airframe members such as landing gear struts, beam caps, brackets and fittings on the IL-10 and MIG-15 have all been made of "chromansil" (CHROmium, MANganese, SILicon) type steels. This type of steel was originally developed by the Germans and reached a certain degree of popularity in Europe. The steel was tried out in the U. S. but never became adopted largely because it is difficult to make ingots of constant composition and free of surface defects. Chromansil steel samples from the MIG-15 have been examined and evaluated previously. 1, 2 & 3/ A literature survey on chromansil steels has also been made and is to be reported in the near future. 3/ The chief advantage of the steel is its low critical alloy content, 1% chromium, compared to 1.8% nickel, 0.8% chromium, 0.25% molybdenum (SAE 4330) steels which would generally be used for similar applications in the U. S. The chief disadvantages of the Soviet steel are its temper brittleness and its low hardenability; these undesirable properties would not allow the substitution of 30XГС type steels for SAE 4330 by U. S. design standards.

Mechanical properties of the steel were determined by testing samples taken from the first YAK-11 engine mount. Duplicate sheet tensile specimens 10 inches long were cut from each length of tubing. The reduced sections were ½ inch side and 2½ inches long. The tensile and hardness data obtained are given in Table 2.

The yield and tensile strengths of the tubing were somewhat lower than the earlier results obtained on the main beam of the MIG-15 horizontal stabilizer. The yield and tensile strengths of the bolt were lower than for the tubing.

The microstructure of the steel samples was generally satisfactory. The engine mount bolts were an exception. The silicate inclusions indicate incomplete deoxidation of the steel. The carbide spheroids and the ferrite indicate that

1/ "Examination of Foreign Aircraft Engine and Airframe Parts," ATIC Technical Report No. 5, 16 August 1951.
2/ "Further Examination of Steel Star in MIG-15 Horizontal Stabilizer," ATIC Technical Report No. 17, 13 December 1951, SECRET.
3/ "Examination of Soviet Low Alloy Steels," ATIC Technical Report No. 37 (to be published), RESTRICTED.

1. Transparent Material

The transparent canopy was not of laminated design, but considering the purpose of the aircraft, it is questionable if the safety afforded by laminated construction would justify the increased expense.

2. Bakelite

The demand-type oxygen regulator for breathing use was made of phenol formaldehyde (Bakelite) plastic. Bakelite plastics are suitable for construction of demand-type regulators. However, American practice is to use pressure-demand regulators and these require aluminum castings. Dimensional requirements of the pressure-demand type of construction are such that it is necessary to use a material which maintains the casting mold dimensions. Plastic materials have been found to change dimensions very slightly with age, and this is sufficient to prevent their use in constructing a pressure-demand-type regulator.

3. Nitrocellulose

Use of nitrocellulose and cellophane as a rubber hose cover (see Rubber section, reference main fuel line transfer hose, Table 6) is a practice which would not be acceptable to U. S. standards. The plastic materials are resistant to fuel and oil, and probably for this reason they are used to protect the rubber which is not resistant. However, cellulose and nitrocellulose are very flammable, and would create a serious fire hazard when used for fuel service.

C. RUBBER

During the analysis of the rubber parts on this airplane, four different types of rubber were identified: natural, polybutadiene, butadiene-styrene, and neoprene. The following discussion highlights the data included in Table 6.

1. Natural Rubber

The following parts were found to be made from natural rubber:

a. Instrument shock mount. This is a good vibration material. There was an excellent bond between the rubber and the metal sleeve.

b. Rubber grommet. Cracks showed poor compounding for age-resistance.

c. Hose coupling from oil filter line. Outside layer only was natural rubber. Permeability of inside layer plus fumes from engine will attach natural rubber. Early replacement would be probable.

2. Polybutadiene

This type of synthetic rubber is not produced in large quantities in the U. S. It has about the same physical properties as butadiene-styrene (GR-S) or natural rubber. The following parts were found to be made from this material:

a. Bumper pad for cockpit canopy. U. S. aircraft engineers would have used a material with better aging characteristics.

b. Fuel transfer hose, main fuel line. This was made of rubber, plastic, and metal. The rubber layer is not fuel-resistant; frequent replacement would be probable. Buna N should have been used; however, neoprene would have been satisfactory.

c. Oil transfer hose, main return line. This was the same construction and materials and same poor choice as noted for fuel hose, above.

d. Chafing strip, for top of fuel tank. Five layers of the same polymer were used but the three center layers were cellular. This is a satisfactory choice of material for the type of application.

e. Chafing strip for bottom of fuel tank. One layer of cellular rubber provides adequate protection.

3. Butadiene-Styrene (Buna S)

This material is the synthetic rubber that can be used in most applications where natural rubber would be applicable. Prior to the analysis of the YAK-11 parts, this material had never been found in Soviet aircraft.

a. Wire insulation. The outside layer of this electrical wire was a butadiene-styrene compound while the inside layer was a blend of the same copolymer with natural rubber. Buna S has exceptionally good electrical insulating properties and is easily extruded for manufacturing wire. This is a good choice of material.

4. Neoprene

This is the only oil-resistant rubber found on the YAK-11. It is far inferior to Buna N and cannot be used in contact with aromatic fuels.

a. Vibration damper for cowling. The material is satisfactory for this application.

b. Hose coupling for oil filter line. The inside layer of this coupling was made from neoprene. This was a better choice than the polybutadiene used in the oil line, above. Buna N would require fewer replacements.

c. Cement bonding five layers of the fuel tank top chafing strip together. Other rubber would make better adhesion cements than neoprene. The cement was good enough for the application but better materials could have been employed.

SECTION VII

MANUFACTURING METHODS

A. AIRFRAME

The aircraft examined, serial number 12216, is thought to have been manufactured in 1950. The type of construction and manufacturing practices observed on the aircraft are similar to those used on earlier YAK-9 fighters and it appears that the YAK-11 trainer is an outgrowth of the YAK-9 series. The YAK-11 is a mixture of various types of construction in which steel tube, light aluminum alloy, and fabric all have their part. Earlier types of YAK-11 fighter trainers have all used these forms of construction to some degree. The first types employed a great deal of wood, plywood and fabric. The aircraft examined, which was of a later manufacturing date, still had fabric on the fuselage tail section, but employed formed aluminum stringers and aluminum alloy sheet as the primary fuselage covering instead of the wood and plywood as on the earlier YAK-9 and YAK-11 series.

1. Fuselage

From a manufacturing standpoint the fuselage has many favorable features: the assembly breakdown is considered adequate for series production in the Soviet environment; the welded tubular steel structure is common to Soviet aircraft and well suited for the facilities available. General purpose machine tools and a minimum of detail tools could be utilized in the manufacture of all fabricated parts; no complex jigs or fixtures would be required. Unskilled labor could be employed in fabrication, sub-assembly and final assembly of the fuselage. The access panels provided in the fuselage not only allow easy access for construction and final assembly operations, but reduce the number of riveting man-hours by the uses of DZUS type fasteners in their installation.

All exterior rivets were flush and acceptable to American aircraft standards. Many interior rivets were not of this quality though apparently acceptable to Soviet standards.

Though a few castings and forgings were found, the Soviets still rely on welded and machined steel fittings for main attachment points.

When compared to the manufacturing practices used in similar American aircraft, the following examples are considered significant:

The welded fuselage structure, though considered obsolete by American standards, is adequate for series production in the Soviet environment.

The assembly breakdown and design of all fabricated parts would not require the complicated jigs, fixtures, or special purpose machine tools used to a great extent in American aircraft manufacture.

The quality of workmanship would be acceptable to American standards.

2. Wing

Upon examination of the wing construction, there were many advantages as well as disadvantages found in the methods employed in its manufacture. Among those of advantage were:

The built-up spar of sheet and extruded aluminum alloy would not require precision machining employed on forged or billet stock. Unskilled labor could be employed in the construction and installation.

Most of the wing skins were of one piece and covered the entire area from the upper rear spar to the lower front spar. The forming of this panel in one piece reduces the number of sub-assembly jigs required to assemble the wing.

The two fuel cell openings in each wing allows access to the wing interior during construction, assembly and installation.

As on the fuselage, the assembly breakdown and design of all fabricated parts would not require any complicated jigs or fixtures or special machine tools in their manufacture.

Some of the disadvantages found in the methods employed were as follows:

Most skin joints were butted rather than lapped; the butt type joint requires more trimming on assembly to insure proper fit.

The fuel access doors were attached to the structure with screws instead of the DZUS type fasteners used on the fuselage. The screws add many man hours to assembly and installation of the fuel doors because of the special fittings riveted to the structure to accept them.

3. Horizontal and Vertical Stabilizer

The construction and manufacturing practices employed on the horizontal and vertical stabilizers are similar to those used in the American aircraft industry at the end of World War II. The design of the fabricated parts and the assembly breakdown of both stabilizers are considered adequate for manufacture in the Soviet environment. The rudder and elevator were also similar to those of aluminum and fabric construction manufactured in American plants at the end of World War II.

B. POWERPLANT MANUFACTURING METHODS ANALYSIS

The Soviet ASh-21 engine is a seven cylinder, air cooled, radial reciprocating engine rated at 690 horsepower. It is essentially of Soviet design and can be considered a conventional type, influenced by years of reciprocating engine development and production experience in the USSR.

The Soviet ASh-21 engine was examined to determine the adaptability of the engine to quantity production methods, and the effect on production and/or on performance resulting from significant departures from manufacturing methods and processes employed in the U. S.

A manufacturing methods analysis of the Soviet ASh-21 engine, power plant of the YAK-11, has already been made. The results were published as ATIC Study No. 102-AE-51/11-34, dated 27 December 1951, entitled "Soviet ASh-21 Aircraft Engine, Manufacturing Methods Analysis". For this reason, the following discussion will be restricted only to highlights.

1. Gears

The functional quality of the critical gears in the ASh-21 engine compares favorably with similar U. S. parts. Checks on backlash in the several gear trains and individual gear eccentricity and run-out showed them to be within acceptable limits. The employment of Maag gear tooth grinders, uncommon in the U. S. aircraft industry, creates a fine abraded pattern on the tooth faces which provides support for an oil film. Durability is thereby enhanced through more effective lubrication. The utilization of the Maag grinder also decreases the probability of scrap during manufacture since there is less likelihood of burning the tooth surfaces during the grinding operation.

2. Cylinders

The cylinder heads on the ASh-21 engine are of cast aluminum alloy while those of the Wright Cyclone 7, the ASh-21's American counterpart, originate as forgings. The forging method of fabrication was substituted for casting in this application, domestically, to improve engine performance. The metallurgical characteristics of the forging permitted an increase in cooling fin area, thus providing greater heat dissipation. This resulted in longer engine service life with the same horsepower rating. Conversely, if the service life had been satisfactory an increase in power rating could have been effected by retaining former permissible head temperatures. To sum up, then, pound for pound the inherent strength of a forged cylinder head is greater than that of a cast head. The fact that casting is still practiced by the Soviets in the manufacture of the ASh-21 may be considered to impose an optimum limit on engine power potential.

It should be noted that less machining time is required in the manufacture of a cast head since the rough casting more closely resembles the final configuration than does the rough forging.

Material analysis is in process to determine the quality of the cylinder head castings on the ASh-21.

3. Crankcase Main Section

The crankcase main sections of the ASh-21 engine were forged of aluminum alloy. This practice was discontinued in the U. S. counterpart when steel was substituted for aluminum alloy. The development of the forged steel crankcase was complementary to the switch from cast to forged cylinder heads. As in the case of cylinder head fabrication the Soviet method of crankcase manufacture can be expected to impose an optimum limit on engine power potential.

4. Supercharger Impeller

A conventional supercharger impeller in a U. S. reciprocating engine has a splined steel bushing inserted in its hub. In the ASh-21 impeller the splines are broached directly into the aluminum alloy hub section, precluding the machining operations necessary to make and insert the bushing and complete the resultant assembly. It has been estimated that the domestic design would cost approximately 10% more to manufacture if the U. S. and Soviet equipment and labor used were comparable.

The critical vane side of the ASh-21 impeller was carefully finished, indicating a high degree of functional quality for this part.

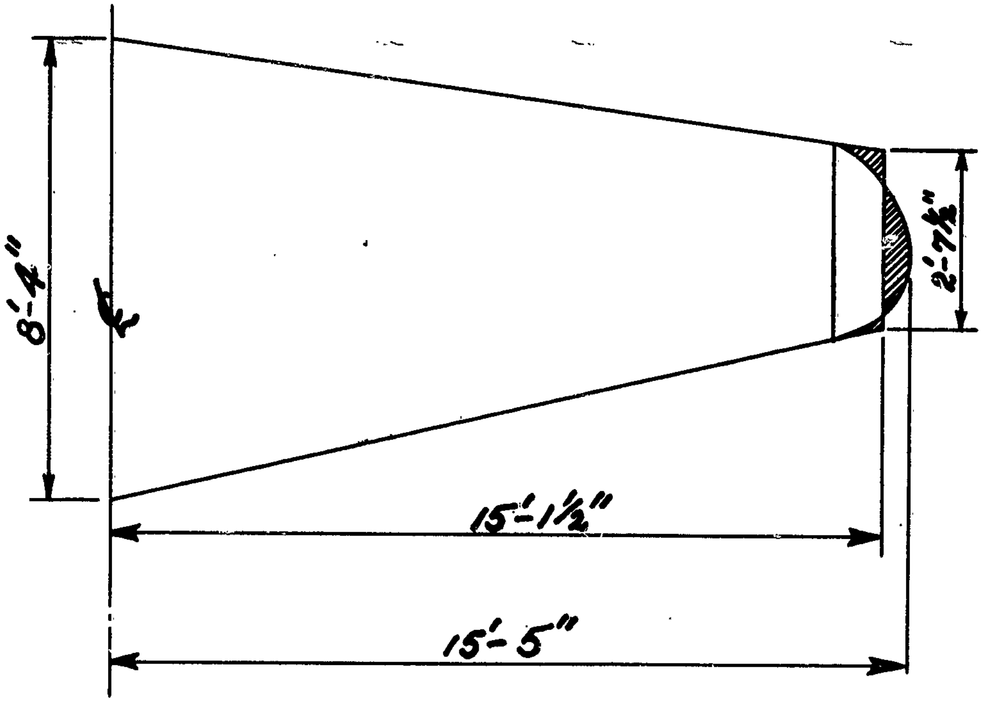
5. Exhaust Valve

The ASh-21 exhaust valve is dissimilar to any commonly used in American reciprocating engines and its fabrication is significant. Briefly stated, the functional quality of the exhaust valve appears to be excellent. Evidently, close control was exercised over manufacture. The unusually large stem diameter facilitates machining, both internally (sodium cavity) and externally.

SECTION VIII

WEIGHT AND BALANCE

A. DETERMINATION OF MEAN AERODYNAMIC CHORD AND WING AREA



AREA

$= \frac{100 + 31.5}{2} \times 181.5 = 82.87$ sq ft/panel

$82.87 \times 2 = 165.7$ sq ft total

MAC (Determined per Army ATSC Manual No. 57-0-1 Section 1, Page 4)

$= \frac{2}{3}\left(100 + 31.5 - \frac{100 \times 31.5}{131.5}\right)$

$= \frac{2}{3}(131.5 - 23.95)$

$= 71.7"$ (Mean Aerodynamic Chord)

LEMAC = 72.5" (Leading Edge of Mean Aerodynamic Chord)

GROUP WEIGHT STATEMENT

ESTIMATED-CALCULATED-ACTUAL

(Cross Out Those Not Applicable)

Model YAK-11

Contract No. ____________

Airplane, Government No. ____________

Airplane, Contractor No. ____________

Built By ____________

Engine (Model) Ash- 21

Engine, Government No. ____________

Date ____________

Changes Incorporated In This Airplane (Nos. of) ____________

____

Other Modifications Incorporated Since The First Airplane Under This Contract ____________

____

____

____

____

____

CODE NO.		PROVISIONS FOR EQUIPMENT	STRUCTURE	LANDPLANE or SEAPLANE
1	WING GROUP			701.4
2	CENTER SECTION (OR UPPER CENTER)			
3	INTERMEDIATE PANEL (OR UPPER OUTER)			
4	OUTER PANEL (OR LOWER CENTER)			
5	TIPS (OR LOWER OUTER)			
6	AILERONS (COUNTER BALANCE WT. LBS.)			
7	FLAPS			
8	SLATS			
9				
10	TAIL GROUP			135
11	STABILIZER		81	
12	ELEVATOR (COUNTER BALANCE WT. LBS.)			
13	FIN		54	
14	RUDDER (COUNTER BALANCE WT. LBS.)			
15				
16	BODY GROUP			751.5
17	FUSELAGE OR GONDOLA - LESS ENG. SECTION			
18	BOOMS			
19	HULL			
20	ALIGHTING GEAR - LAND TYPE			295.5
21	MAIN LANDING GEAR		280	
22	AUXILIARY LANDING GEAR (NOSE OR TAIL WHEEL)		15.5	
23	BUMPER (WHEEL OR SKID)			
24				
25	ALIGHTING GEAR - WATER TYPE			
26	MAIN FLOATS			
27	AUXILIARY FLOATS			
28	ENGINE SECTION or NACELLE GROUP			78
29	INNER		78	
30	CENTER			
31	OUTER			
32				
33	POWER PLANT GROUP			1425.7
34	ENGINE (AS INSTALLED)		935	
35	ENGINE ACCESSORIES		127.1	
36	POWER PLANT CONTROLS			
37	PROPELLERS		195	
38	STARTING SYSTEM		7.5	
39				
40	COOLING SYSTEM		27.1	
41	RADIATORS & SHUTTERS 27.1			
42	LIQUID			
43	PIPING ETC.			
44	LUBRICATING SYSTEM		50.3	
45	TANKS AND PROTECTION 50.3			
46	PIPING ETC.			
47	FUEL SYSTEM		83.7	
48	TANKS AND PROTECTION 83.7			
49	PIPING ETC.			
50	TOTALS (TO BE BROUGHT FORWARD)			3387.1

CODE NO.				ANDPLANE or SEAPLANE
1	FIXED EQUIPMENT GROUP			423.9
2	INSTRUMENTS		43.6	
3	SURFACE CONTROLS		84.1	
4	~~xxxxxxxxxxxx~~ Pneumatic		75.5	
5	ELECTRICAL		84.6	
6	COMMUNICATING		68.2	
7	ARMAMENT PROVISIONS (INCLUDING GUNFIRE PROTECTION)		41.4	
8	FURNISHINGS		26.5	
9	PERSONNEL ACCOMMODATIONS	26.5		
10	EMERGENCY ACCOMMODATIONS			
11	PROVISIONS FOR FLIGHT			
12	AIR CONDITIONING EQUIPMENT			
13	ANTI-ICING EQUIPMENT			
14	AUXILIARY POWER PLANT			
15	AUXILIARY GEAR			
16	ANCHOR, TOWING & HOISTING GEAR			
17	ARRESTING GEAR INSTALLATION			
18	EMERGENCY FLOTATION GEAR			
19	SERVICE PICKUP			
20	TOTALS (FROM PAGE 2.0)			3387.1
21	WEIGHT EMPTY			3811.0

UNIT WEIGHTS

WING GROUP (GROSS AREA SQ.FT.) LBS. PER SQ.FT.	
TAIL GROUP (GROSS AREA SQ.FT.) LBS. PER SQ.FT	
SUBMERGED DISP. MAIN FLOATS OR HULL ( )	
WEIGHT OF MAIN FLOATS AND BRACING ( )	
WEIGHT OF COOLING SYSTEM PER NORMAL H.P. (H.P.)	
WEIGHT OF LUBRICATING SYSTEM PER GAL. OIL CAP. (GAL. OF OIL)	
WEIGHT OF FUEL SYSTEM PER GAL. CAP. (GAL. OF FUEL)	

DESIGN INFORMATION

LENGTH - MAX.	MAXIMUM FUSELAGE DEPTH
HEIGHT - MAX.	MAXIMUM FUSELAGE WIDTH
SPAN	DESIGN GROSS WEIGHT
THICKNESS ROOT CHORD	GROSS WEIGHT FOR STRESS ANALYSIS
THICKNESS TIP CHORD	
WING AREA - NET	
LOAD FACTOR - ULTIMATE	
TAPER RATIO (ROOT CHORD/TIP CHORD)	
LENGTH ROOT CHORD	TOTAL BULLET PROOF GLASS POUNDS
LENGTH TIP CHORD	TOTAL ARMOUR PLATE POUNDS

REMARKS

"PROVISIONS FOR" CAN BE INTERPRETED AS FOLLOWS:

1. ALL PARTS ASSEMBLED TO ONE BASIC UNIT FOR THE SOLE PURPOSE OF PRODUCING A SUPPORT OR MOUNT FOR EQUIPMENT OR STRUCTURAL UNITS OF ANOTHER BASIC GROUP.
2. IF THE CONTRACTOR'S SYSTEM OF WEIGHT BREAKDOWN INCLUDES ITS PROVISIONS WITH THE BASIC GROUPS, THEN WEIGHTS ORDINARILY ENTERED ON PAGES TITLED "INSTALLATION PROVISIONS FOR" ARE NOT REQUIRED.

SERVICE PICK-UP DOES NOT INCLUDE ENTRAPPED FUEL & OIL

USEFUL LOAD

	LOAD CONDITION	LANDPLANE (SPEC.)	SEAPLANE (SPEC.)	LANDPLANE (ACTUAL)	SEAPLANE (ACTUAL)
1	CREW (NO. 2)	400			
2					
3	PASSENGERS (NO.)				
4	FUEL - ENGINE (359.5 lit) (94.98 GALS.)	569.9			
5	FUEL - TRAPPED IN SYSTEM (GALS.)				
6	FUEL - AUXILIARY POWER PLANT (GALS.)				
7	OIL - ENGINE (37.5 lit (9.91 GALS.)	74.3			
8	OIL - TRAPPED IN SYSTEM (2 GALS.)	15.0			
9	OIL - AUXILIARY POWER PLANT (GALS.)				
10	OIL - SUPERCHARGER (GALS.)				
11	OIL - REDUCTION GEAR BOX (GALS.)				
12	BAGGAGE				
13					
14	CARGO				
15					
16	ARMAMENT				
17	FIXED GUNS (TOTAL)				
18	12.7 mm ~~CAL~~. GUN INSTALLATION Berisina	47.3			
19	100 rds ~~CAL~~ AMMUNITION	37.1			
20	CAL. GUN INSTALLATION				
21	CAL. AMMUNITION				
22	MM. CANNON INSTALLATION				
23	MM. AMMUNITION				
24					
25		E			
26	GUN SIGHTS	23			
27	FLEXIBLE GUNS (TOTAL)				
28	CAL. GUN INSTALLATION				
29	CAL. AMMUNITION				
30	CAL. GUN INSTALLATION				
31	CAL. AMMUNITION				
32	MM. CANNON INSTALLATION				
33	MM. AMMUNITION				
34					
35					
36	BOMB INSTALLATION				
37					
38	2 x 110#	220			
39	TORPEDO INSTALLATION				
40					
41					
42	EQUIPMENT				
43	NAVIGATION				
44	OXYGEN	32.3			
45	PHOTOGRAPHIC Gun Camera	13.9			
46	PYROTECHNICS				
47	MISCELLANEOUS Oblique Camera	30.8			
48					
49					
50	USEFUL LOAD	1463.6			
51	WEIGHT EMPTY	3811			
52	GROSS WEIGHT	5274.6			

WEIGHT AND BALANCE

ITEM	WT.	ARM	MOMENT
Fuselage	751.4	102	76,642.8
Wing	701.4	96	67,334.4
Vertical Stabilizer Assy.	81	298	24,138
Horizontal Stabilizer Assy.	54	282	15,228
Landing Gear Main	280	73.5	20,580
Tail Gear	15.5	288	4,464
Engine Nacelle	78	30	2,340
Power Plant (Basic)	935	31.5	29,452.5
Engine Accessories	127.1	51	6,350
Propeller Assy.	195	4.6	900
Starter	7.5	13	97.5
Cooling System	27.1	10	271
Lubrication System	50.3	81.6	4,103.5
Fuel System	83.7	106.8	8,939.5
Instruments	43.6	123.8	5,399
Surface Controls	84.1	150.7	12,674.8
Pneumatic System	75.6	91.7	6,933.1
Electrical System	84.6	116.8	9,884
Communications	68.2	180.0	12,278.7
Armament	41.4	76.6	3,170.5
Furnishings	26.5	122.1	3,234.3
Pilot	200	106.5	21,300
Co-pilot	200	137.6	27,520
Fuel, Wing Tanks	548.5	105	57,592.5
Fuel, Center Sump Tank	21.4	122.1	2,612.9
Oil	74.3	74.1	5,505.6
Berizina, 12.7mm machine gun	47.3	64.5	3,050.9
Ammunition 100 rds.	37.1	64.5	2,393
Sight	23	86.5	1,989.5
Bombs	220	88.5	19,470
Oxygen System	32.3	135.4	4,387.4
Gun Camera	13.9	81.3	1,130.1
Oblique Camera	30.8	173.7	5,350
Oil Sump	15	31.5	472.5
TOTAL	5,274.6	88.6	467,190

C. LOADING CONDITIONS

Max Gross Weight

(Full fuel, Two pilots, Ammunition and 2-110# Bombs)

Weight	Arm	Moment
5,274.6	88.6	467,190

LEMAC = 72.5
MAC = 7.17

$$\frac{16.1}{71.7} = 22.5\% \text{ of the MAC}$$

Operational Empty

(No fuel, Two pilots, No ammunition and No bombs)

	Weight	Arm	Moment
	5,274.6		467,190
Fuel	- 548.5		- 57,592.5
Ammunition	- 37.1		- 2,393
Bombs	- 220		- 19,470
	4,469	86.76	387,734.5

LEMAC = 72.5
MAC = 71.7

$$\frac{14.26}{71.7} = 19.9\% \text{ of the MAC}$$

Max Gross Weight

(Full fuel, Single pilot in the front cockpit, Ammunition and 2-110# Bombs)

	Weight	Arm	Moment
	5,274.6		467,190
Co-pilot	- 200		- 27,520
	5,074.6	86.64	439,670

LEMAC = 72.5
MAC = 71.7

$$\frac{14.14}{71.7} = 19.7\% \text{ of the MAC}$$

Operational Empty

(No fuel, Single pilot in the front cockpit, No bombs, and No ammunition)

	Weight	Arm	Moment
	5,074.6		439,670
Fuel	- 548.5		- 57,592.5
Ammunition	- 37.1		- 2,393
Bombs	- 220		- 19,470
	4,269	84.38	360,214.5

LEMAC = 72.5
MAC = 71.7

$$\frac{11.88}{71.7} = 16.6\% \text{ of the MAC}$$

Max Gross Weight

(Full fuel, Two pilots, Ammunition and No-bombs)

	Weight	Arm	Moment
	5,274.6		467,190
Bombs	- 220		- 19,470
	5,054.6	88.58	447,720

LEMAC = 72.5
MAC = 71.7

$\frac{16.08}{71.7}$ = 22.4% of the MAC

Operational Empty

(No fuel, Two pilots, No ammunition and No bombs)

	Weight	Arm	Moment
	5,054.6		447,720
Fuel	- 548.5		- 57,592.5
Ammunition	- 37.1		- 2,393
	4,469	86.76	387,734.5

LEMAC = 72.5
MAC = 71.7

$\frac{14.26}{71.7}$ = 19.9% of the MAC

Max Gross Weight

(Full fuel, Two pilots, Ammunition and No bombs)

	Weight	Arm	Moment
	5,274.6		467,190
Bombs	- 220		- 19,470
	5,054.6	88.58	447,720

LEMAC = 72.5
MAC = 71.7

$$\frac{16.08}{71.7} = 22.4\% \text{ of the MAC}$$

Operational Empty

(No fuel, Two pilots, No ammunition and No bombs)

	Weight	Arm	Moment
	5,054.6		447,720
Fuel	- 548.5		- 57,592.5
Ammunition	- 37.1		- 2,393
	4,469		387,734.5

LEMAC = 72.5
MAC 71.7

$$\frac{14.26}{71.7} = 19.9\% \text{ of the MAC}$$

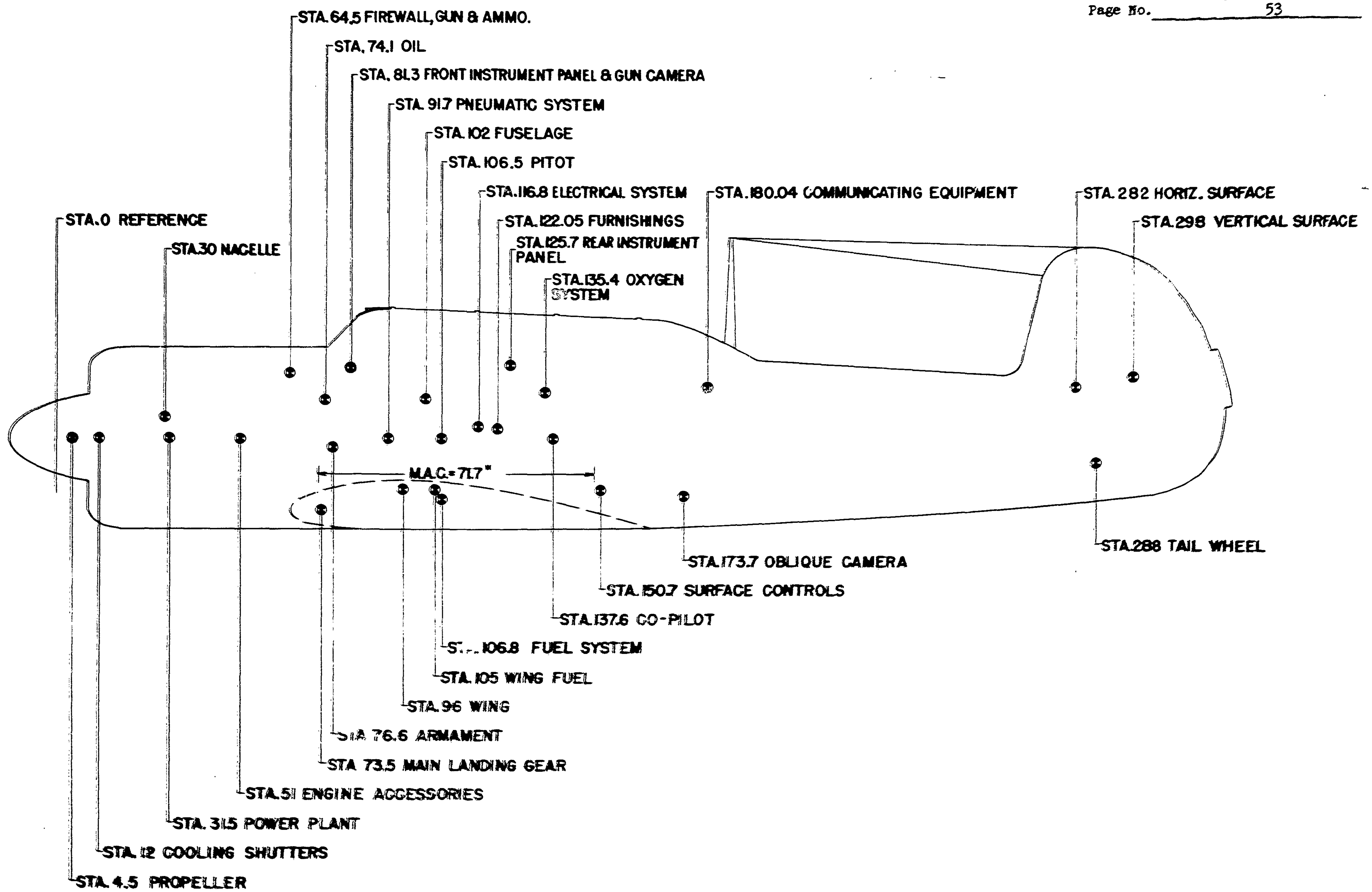


Fig. 11 Weight and Balance Diagram

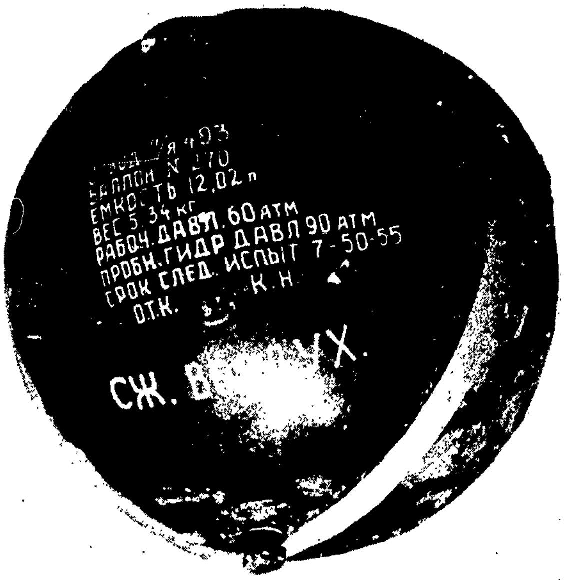


Fig. 12 Main Storage Bottle

Fig. 13 Emergency Air Storage Bottle

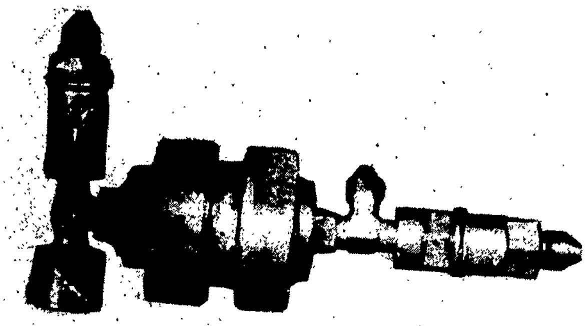


Fig. 14 Pad Filter, Pneumatic System

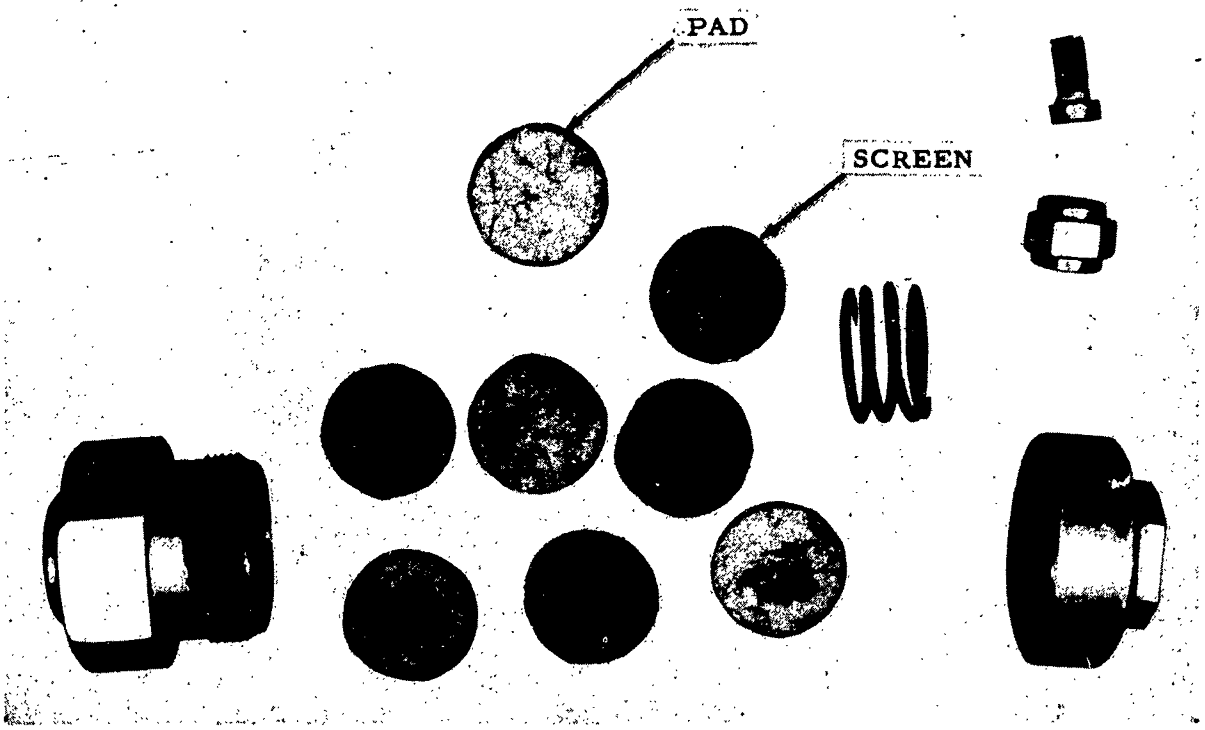


Fig. 15 Pad Filter, Pneumatic System

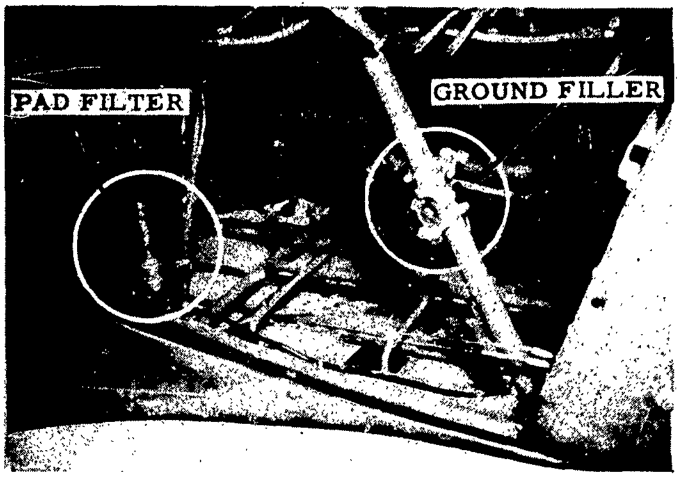


Fig. 16 Pad Filter and Ground Filler
Pneumatic System

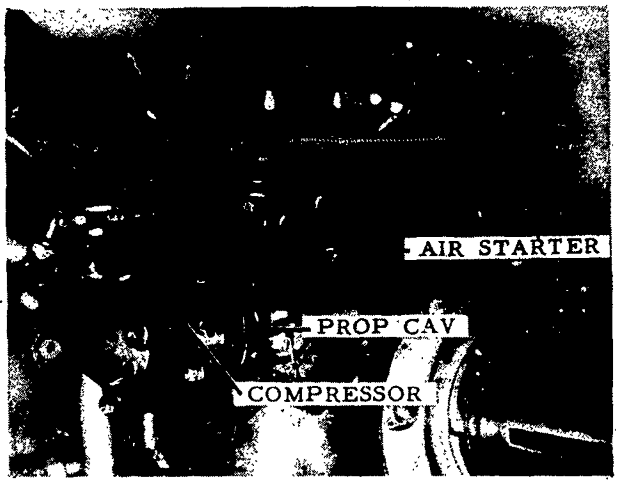


Fig. 17 Compressor, Pneumatic System

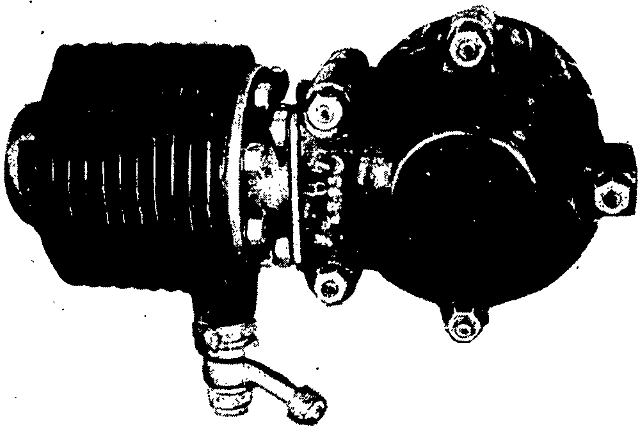


Fig. 18 Compressor, Pneumatic System

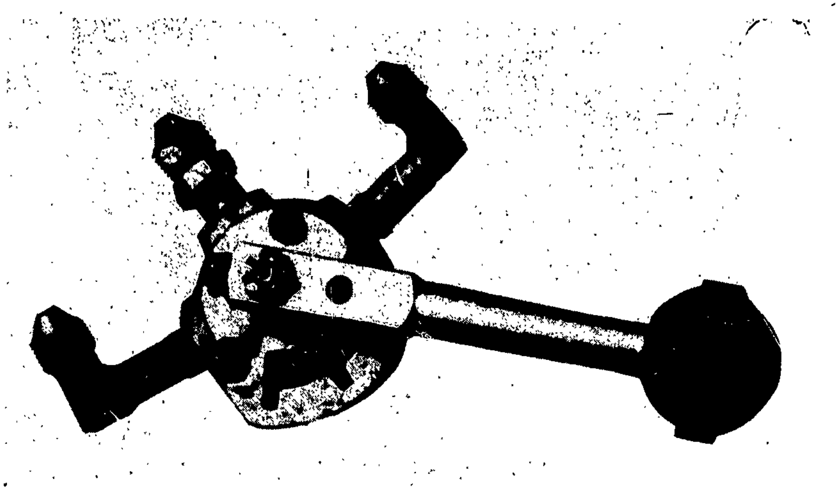


Fig. 19 Landing Gear/Flap Selector Valve, Pneumatic System

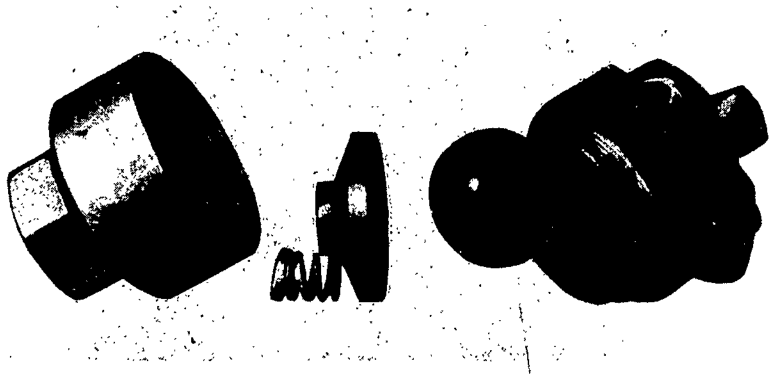


Fig. 20 Landing Gear/Flap Selector Valve, Pneumatic System

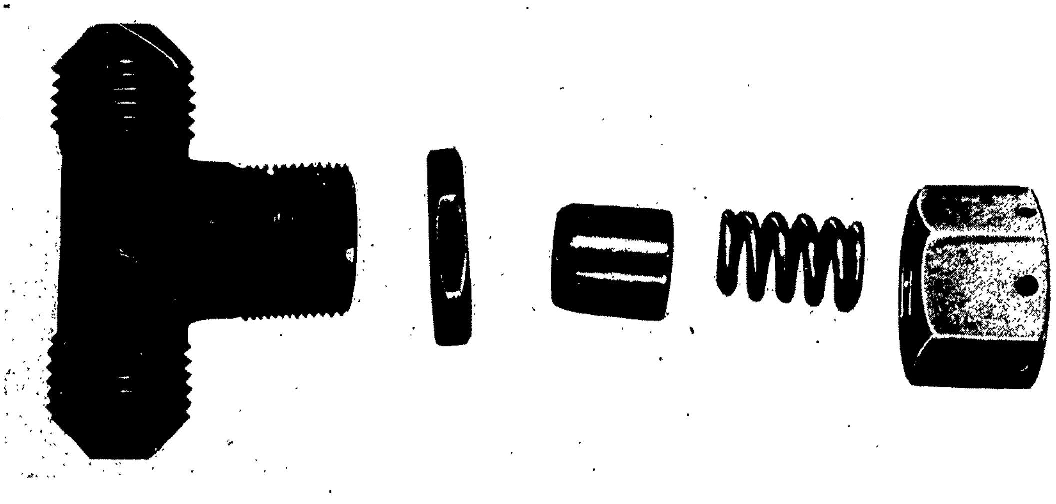


Fig. 21 Pressure Relief Valve, Pneumatic System

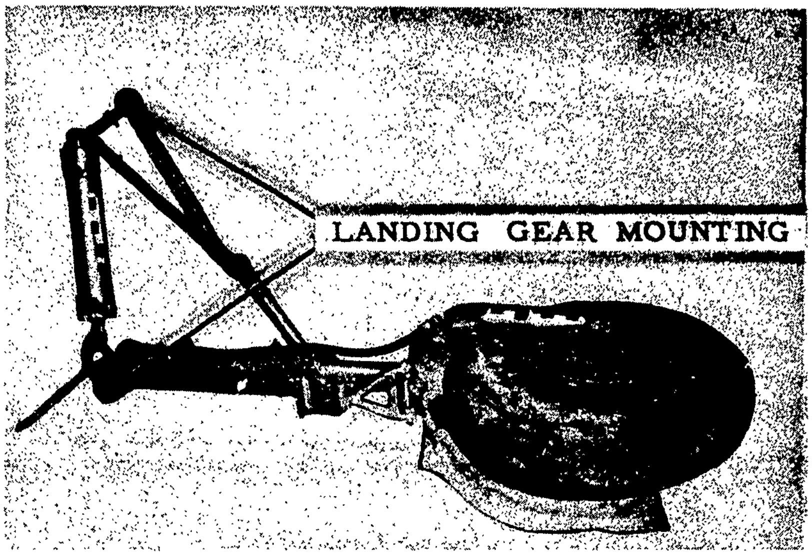


Fig. 22 Landing Gear Assembly

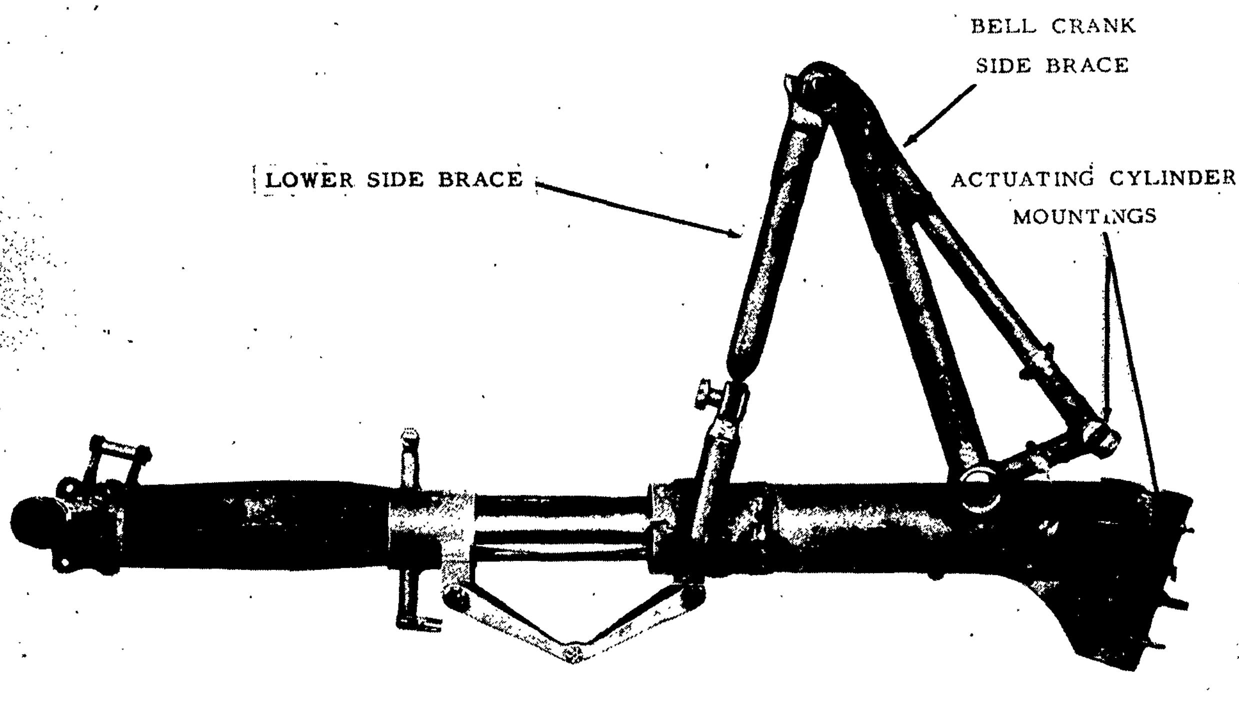


Fig. 23 Landing Gear Strut

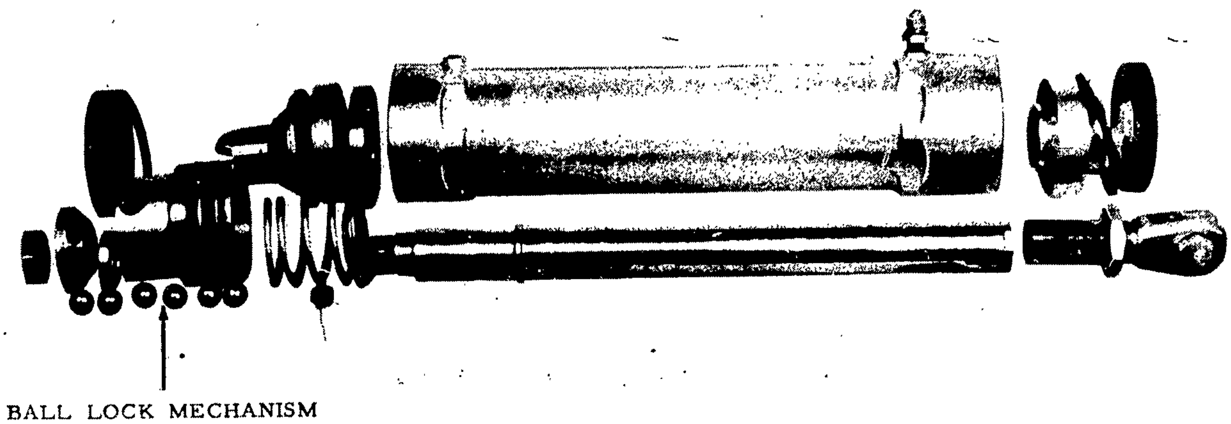


Fig. 24 Landing Gear Actuating Cylinder, Pneumatic System

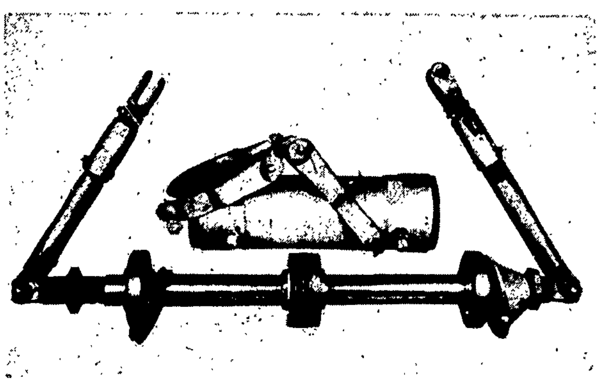


Fig. 25 Flap Actuating Cylinder, Pneumatic System

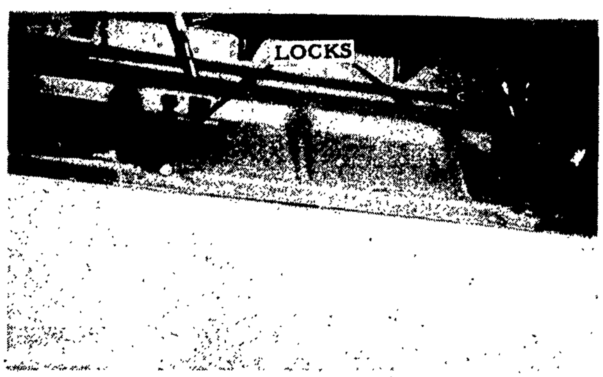


Fig. 26 Mechanical Flap Up Locks

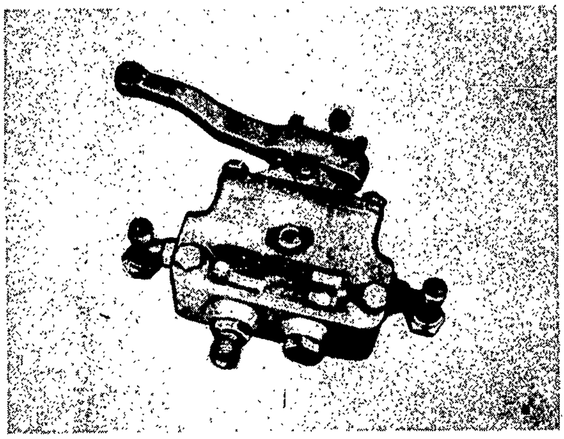


Fig. 27 Brake Differential Valve, Pneumatic System

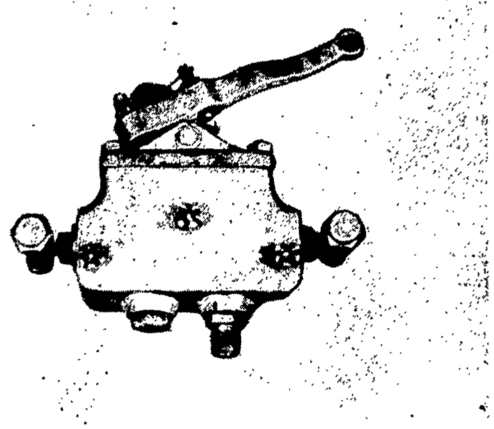


Fig. 28 Brake Differential Valve, Pneumatic System

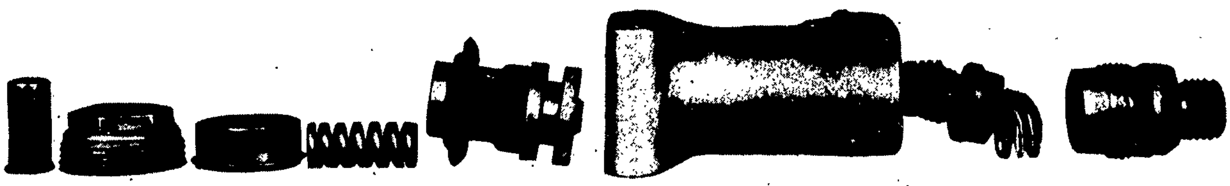


Fig. 29 Brake Bleed Valve, Pneumatic System

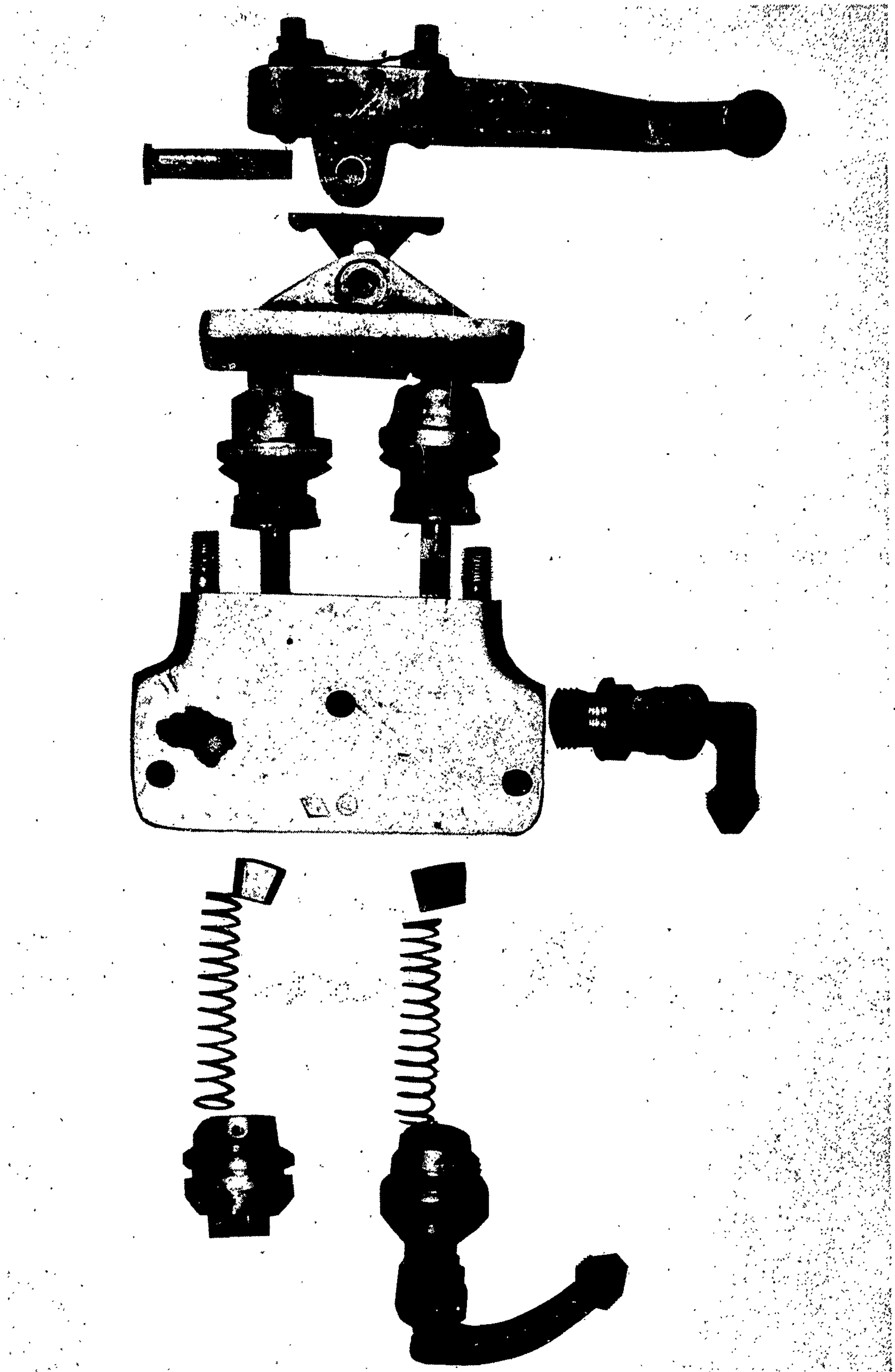


Fig. 30 Brake Differential Valve, Pneumatic System

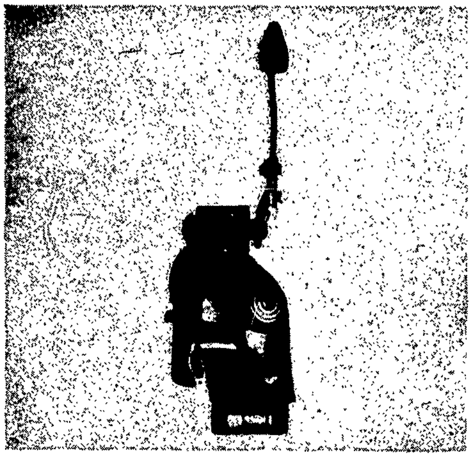


Fig. 31 Front Control Stick

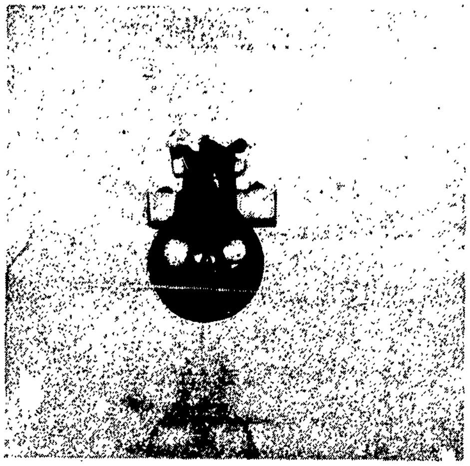


Fig. 32 Top View of Rear Control Stick

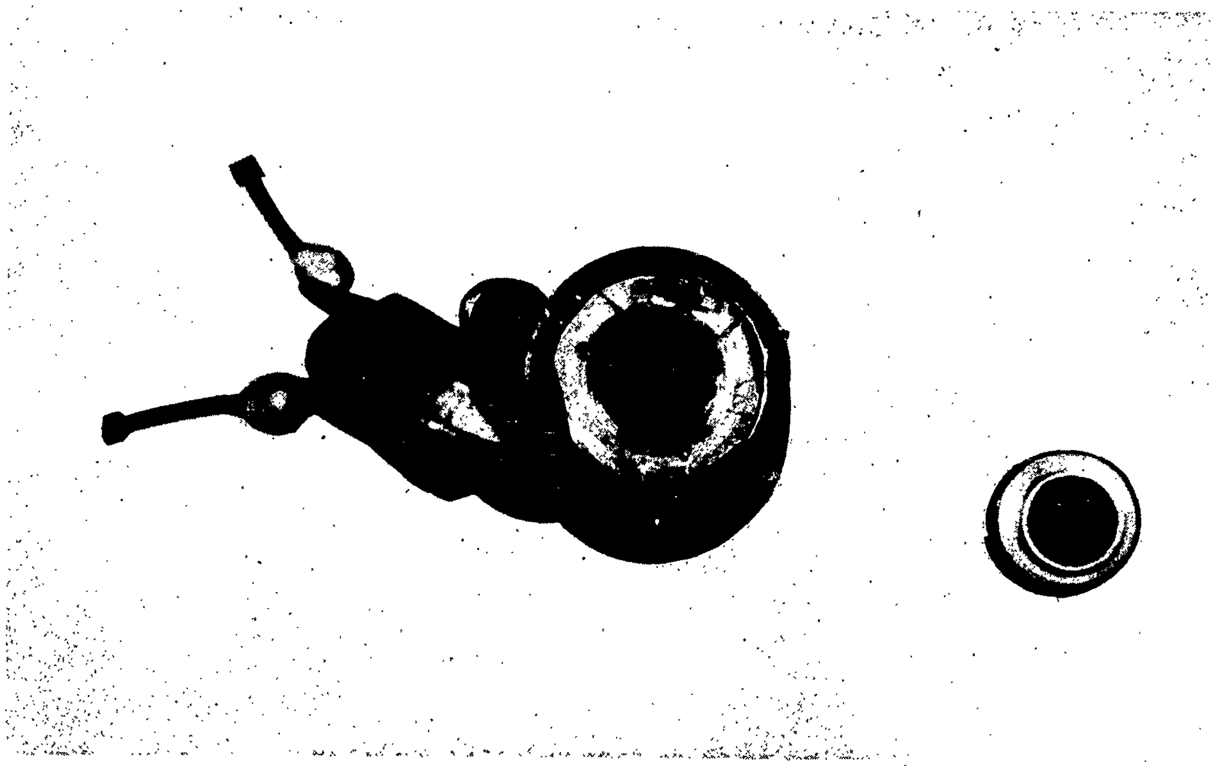


Fig. 33 Emergency Brake Release Valve, Rear Control Stick

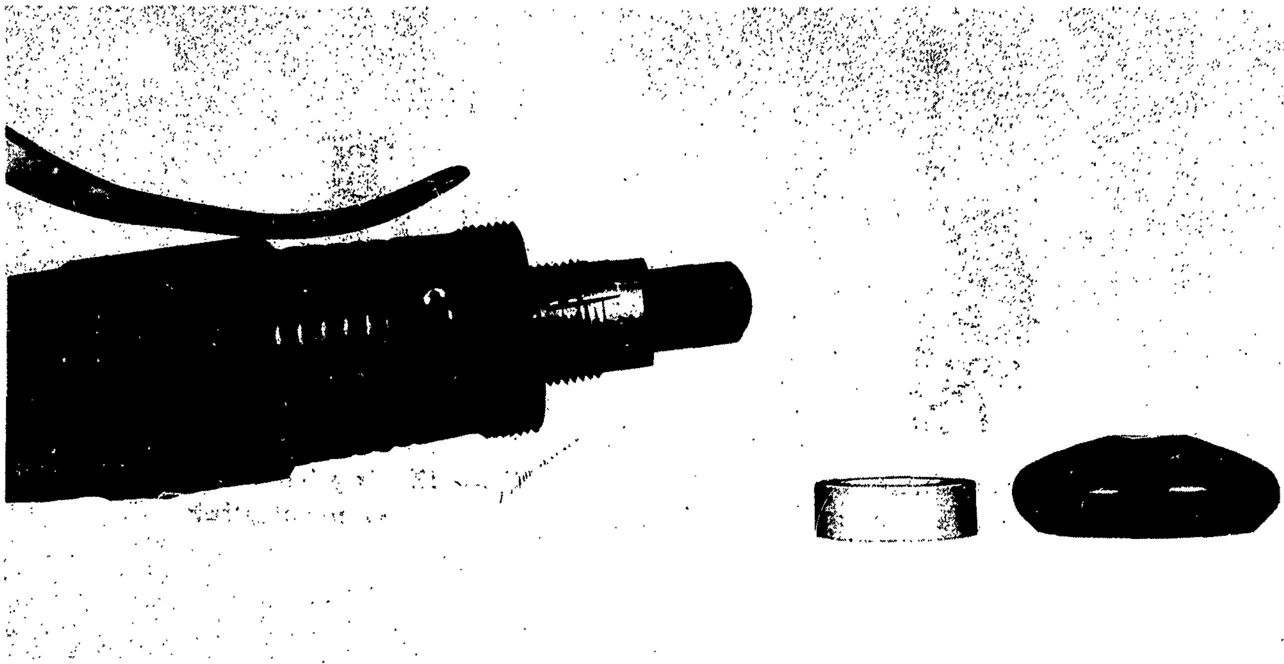


Fig. 34 Emergency Brake Release, Rear Control Stick

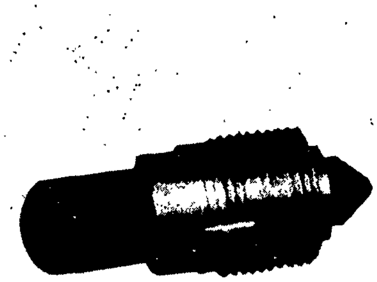


Fig. 35 Emergency Brake Release
Valve Button

Fig. 36 Wheel, Tire and Brake Drum Assembly

Fig. 37 Wheel and Tire Assembly

Fig. 38 Wheel Brake Assembly

Fig. 39 Wheel Brake Assembly

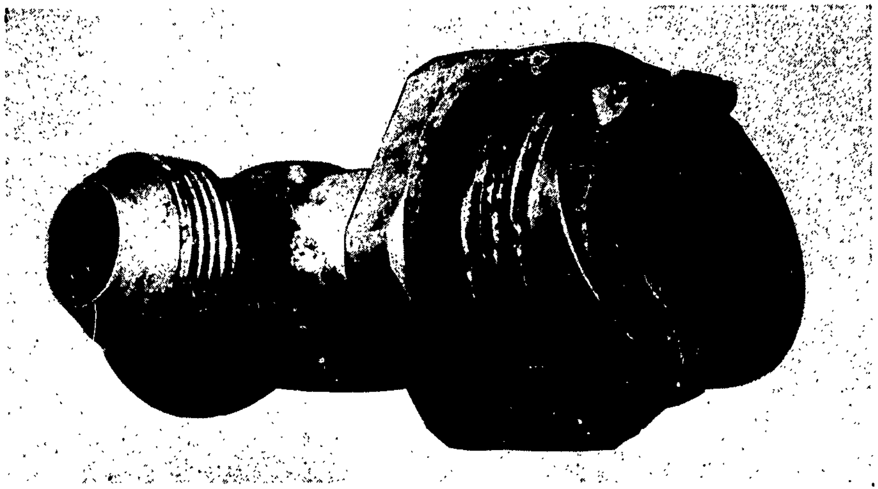


Fig. 40 Fuel Line Flapper Valve

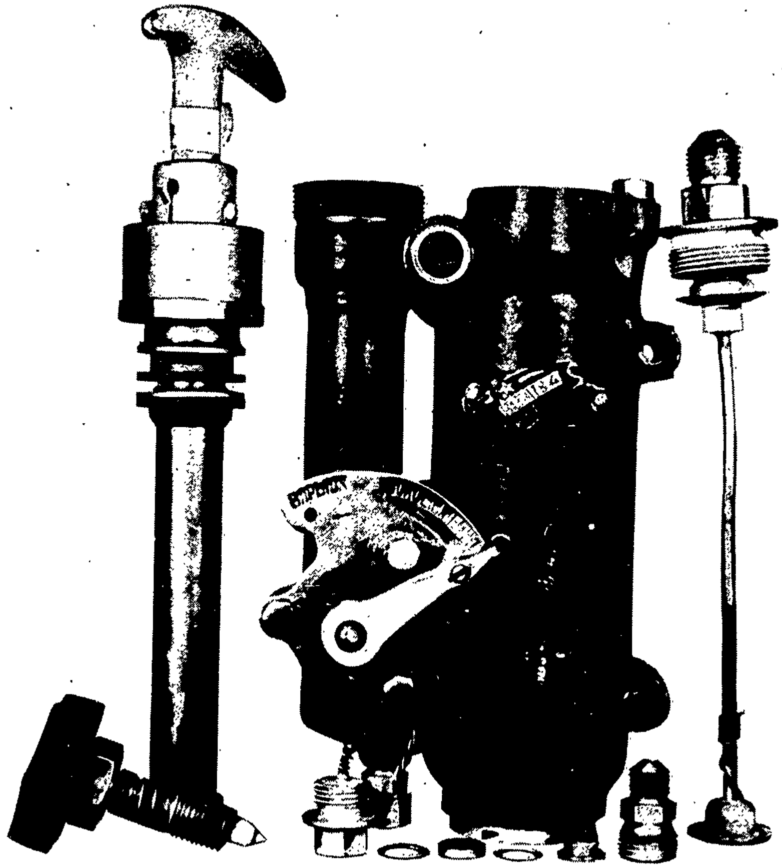


Fig. 41 Priming Pump, Fuel System

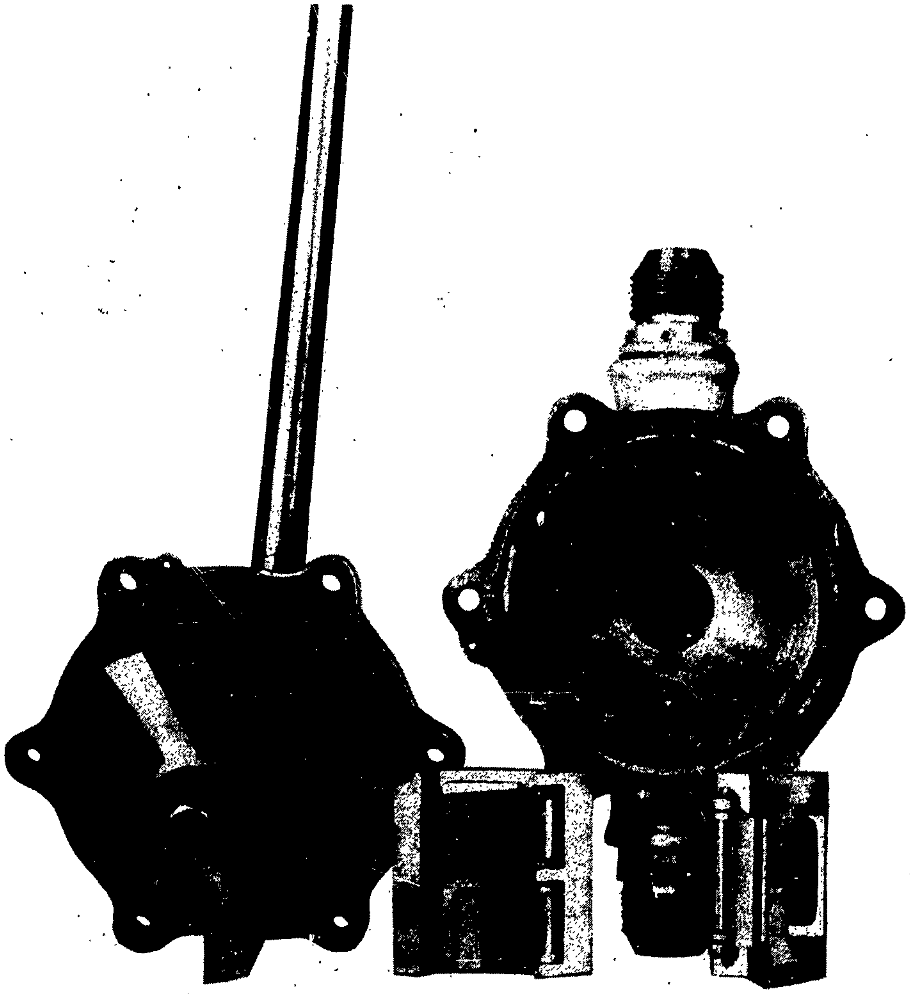


Fig. 42 Wobble Pump, Fuel System

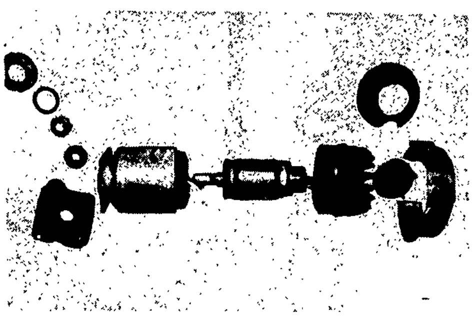


Fig. 43 Generator

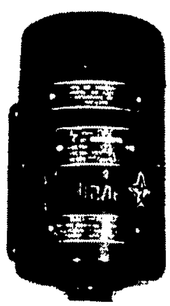


Fig. 44 Inverter

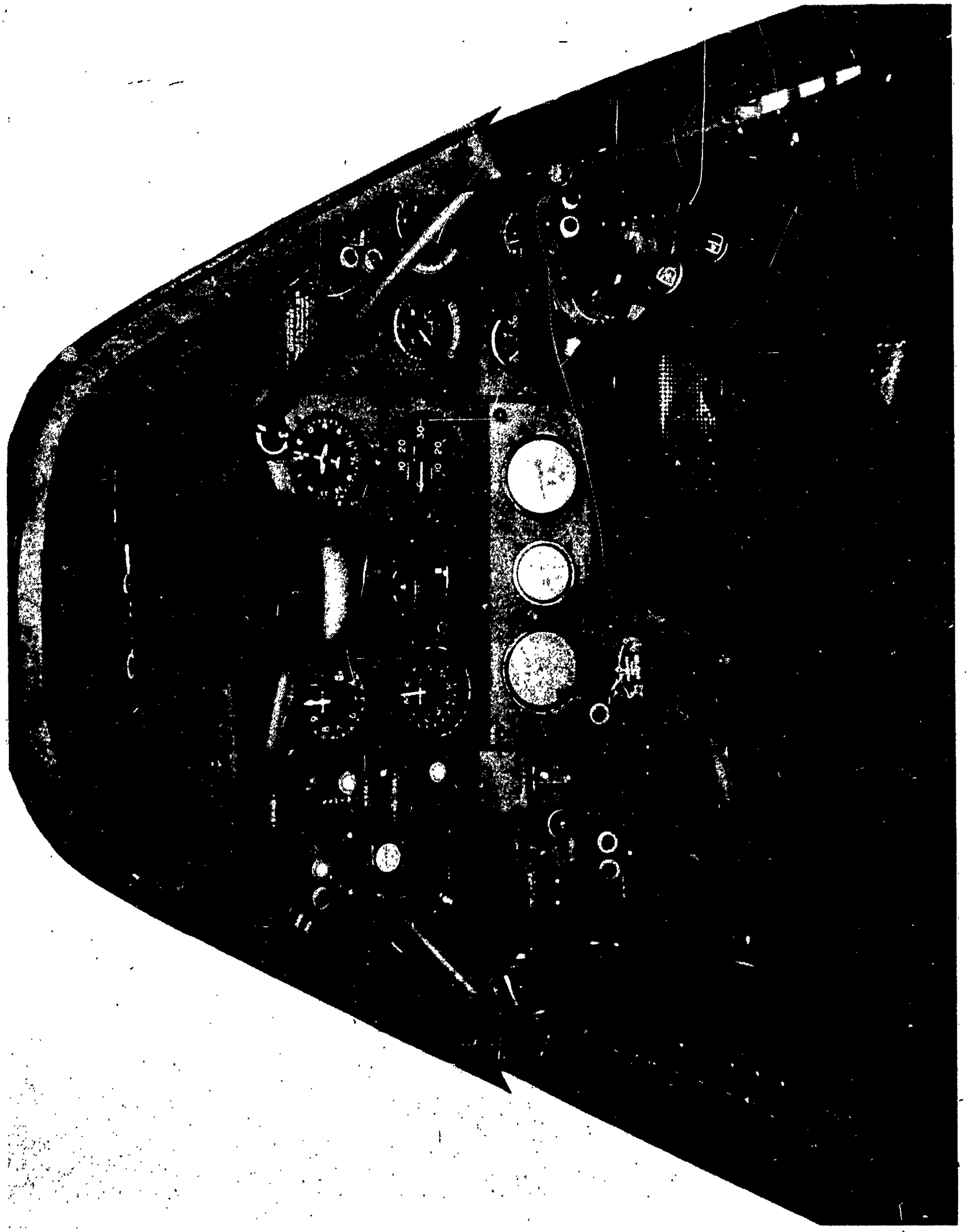


Fig. 45 Front Cockpit

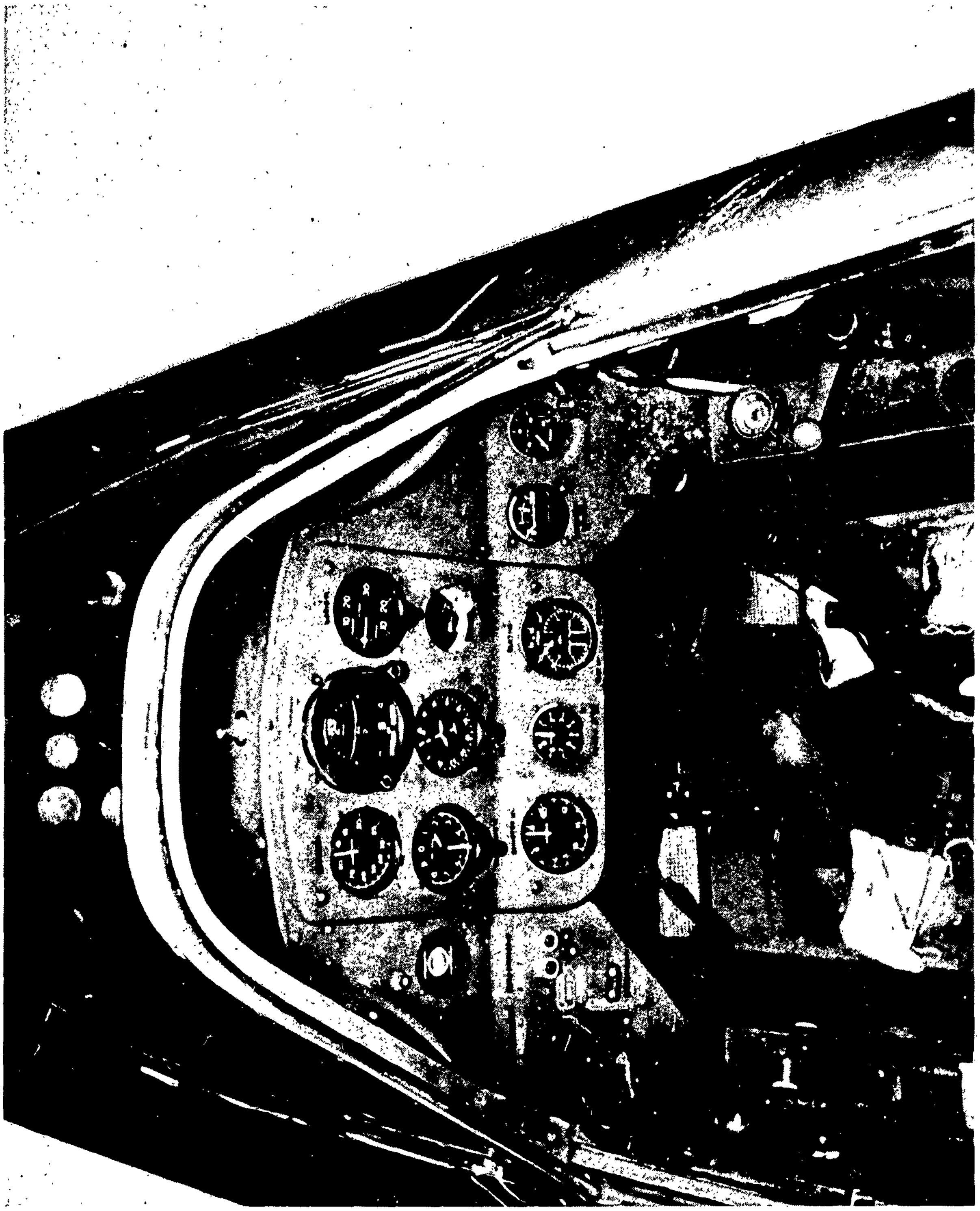


Fig. 46 Rear Cockpit

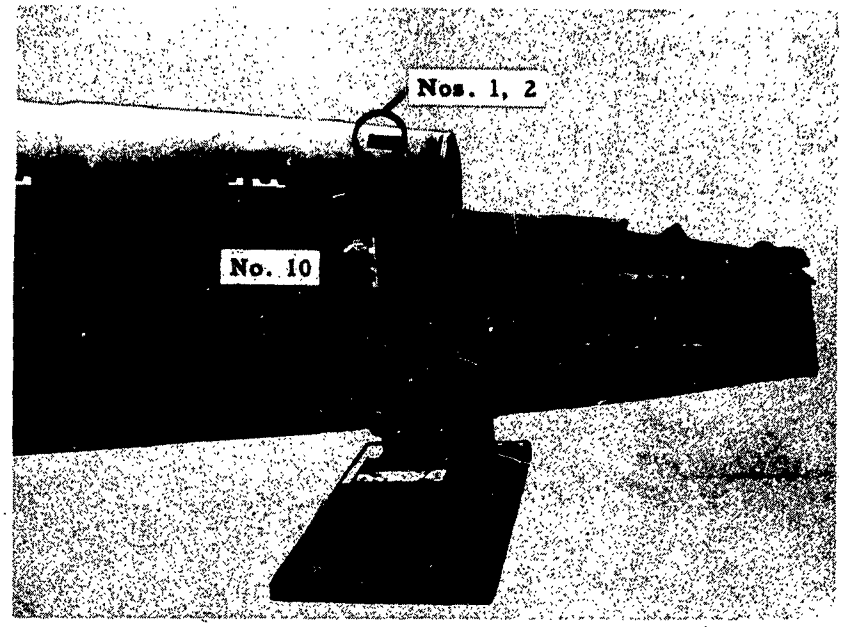


Fig. 47 Location of Metals Samples

Fig. 48 Location of Metals Samples

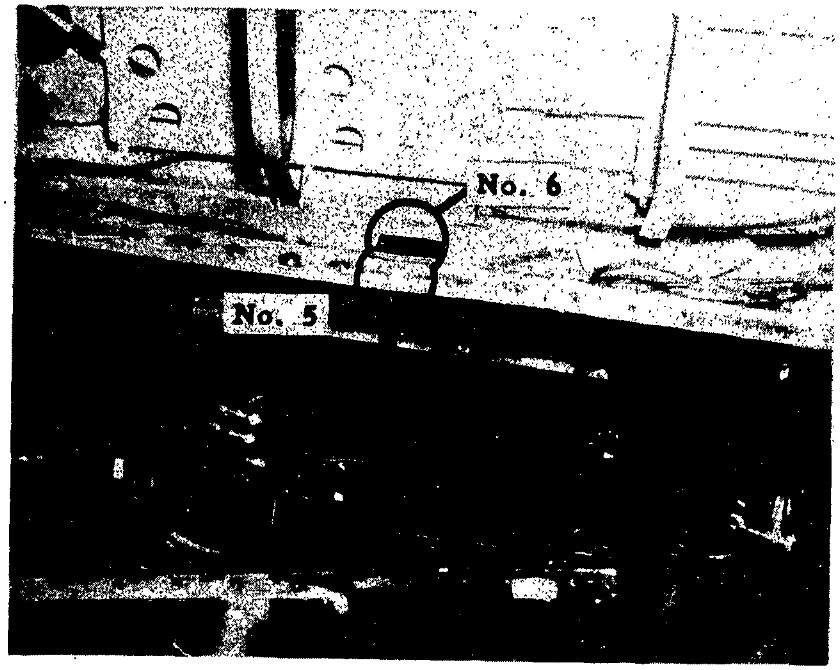


Fig. 49 Location of Metals Samples

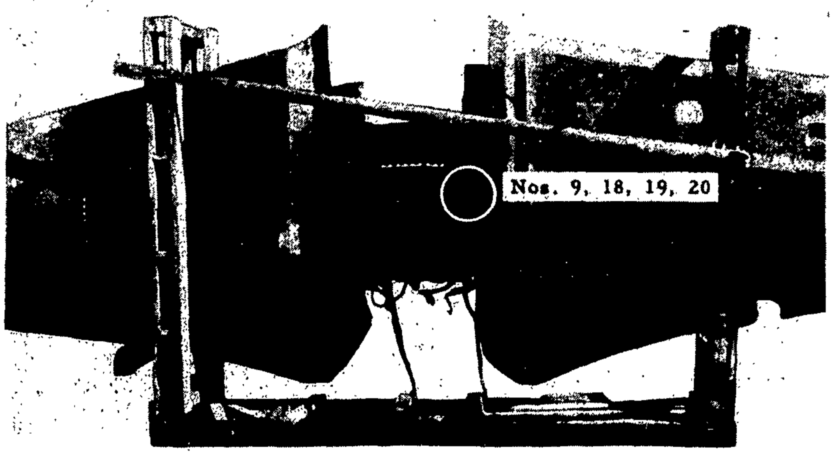


Fig. 50 Location of Metals Samples

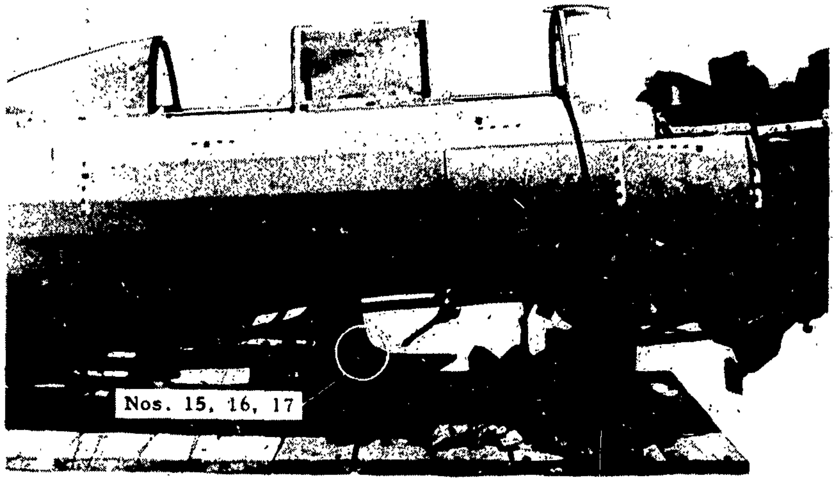


Fig. 51 Location of Metals Samples

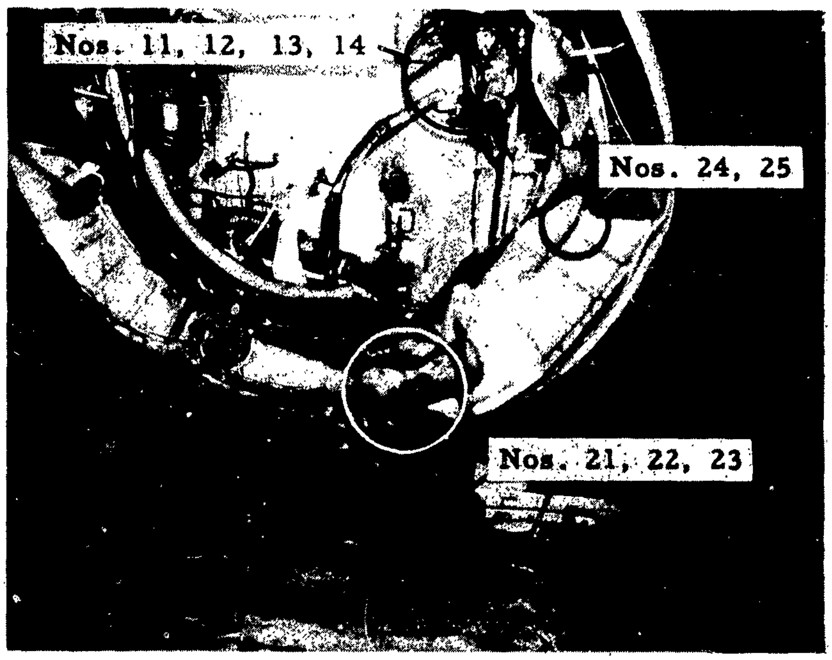


Fig. 52 Location of Metals Samples

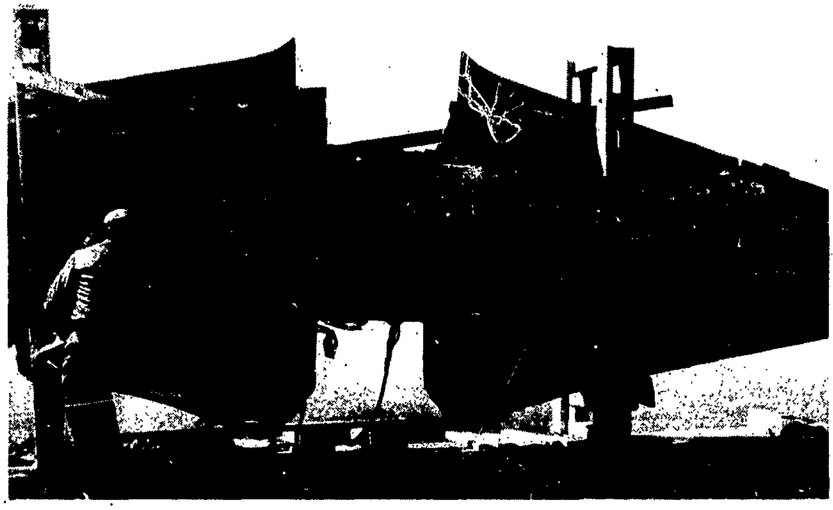


Fig. 53 Underside of Wing

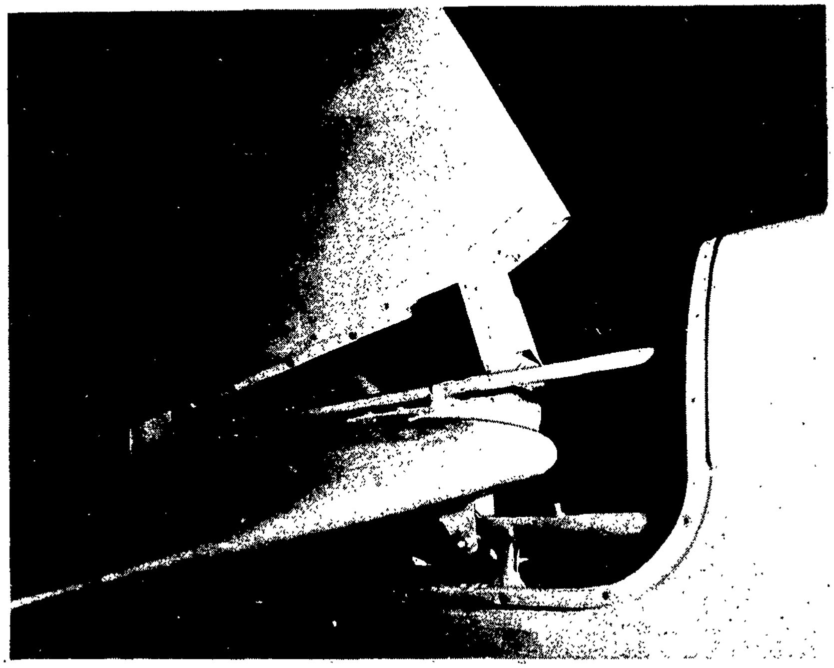


Fig. 54 Empennage Attachment to the Fuselage

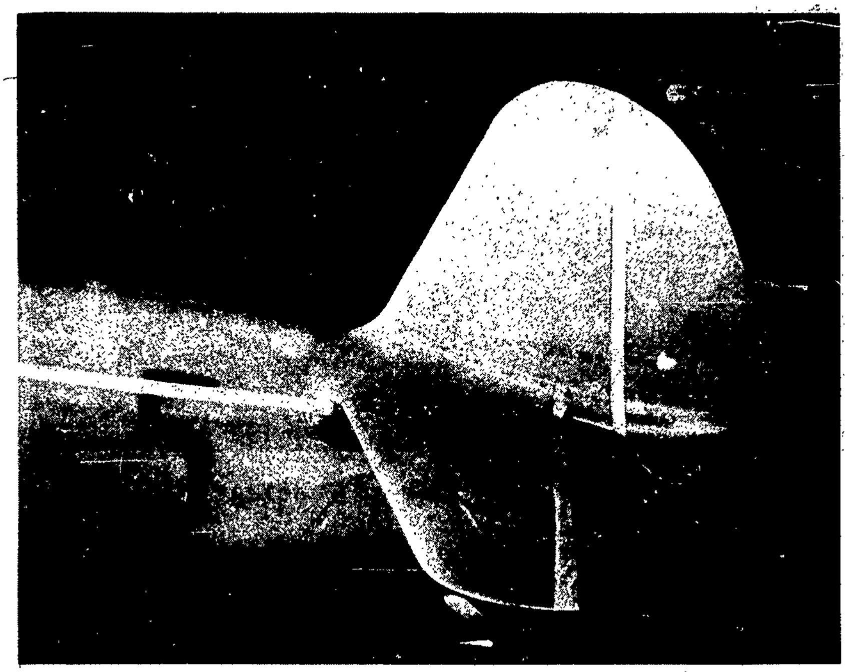


Fig. 55 Empennage

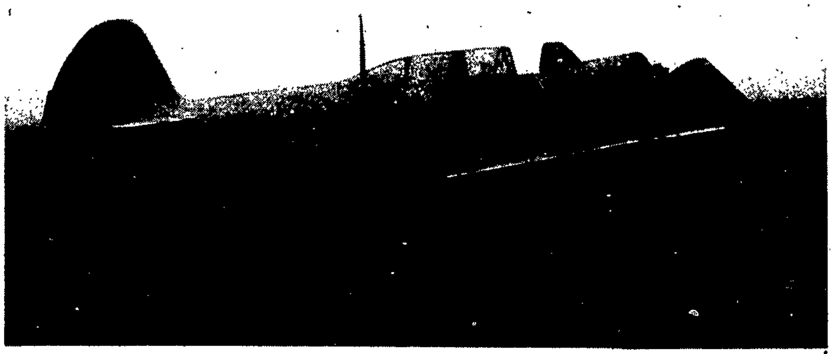


Fig. 56 Right Side of Fuselage

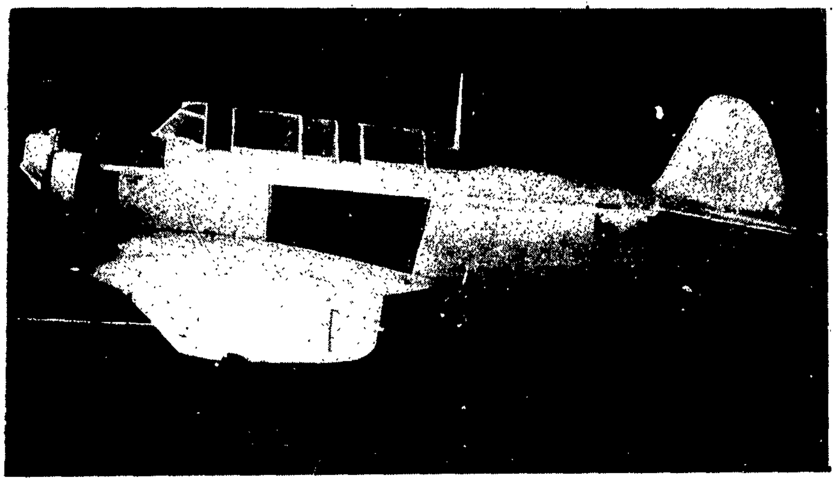


Fig. 57 Left Side of Fuselage

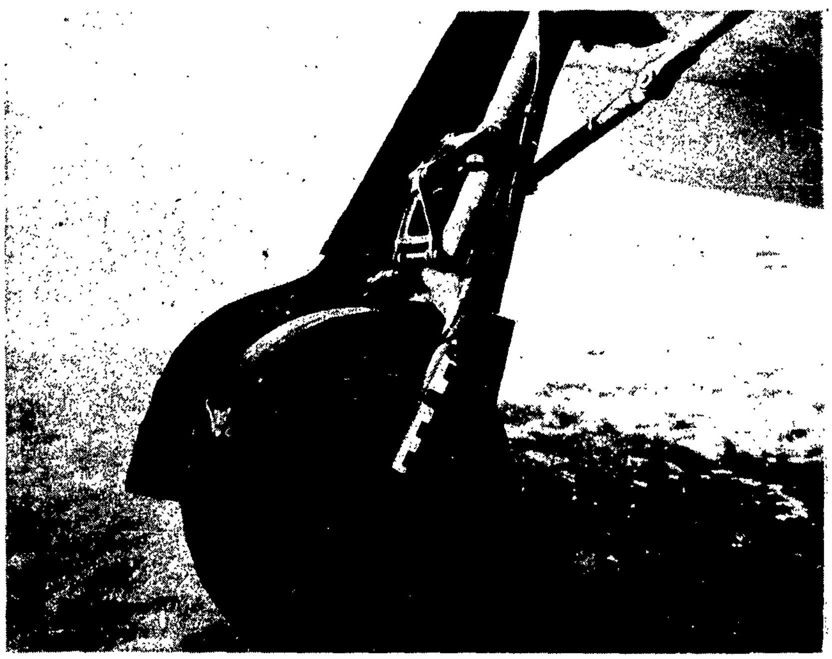


Fig. 58 Right Landing Gear

TABLE I COMPARATIVE MECHANICAL PROPERTIES OF AK6 AND U.S. ALUMINUM ALLOYS

Alloy and Temper	Tensile Strength p.s.i.	Yield Strength p.s.i.	Elongation, Per Cent	Brinell Hardness, (500-kg. load)
AK6 (-T6)(1,2)	65,000	56,000	16	124
AK6 (-T6)(3)	60,000	43,000	13	105
17S -T4 (4)	62,000	40,000	22	105
14S -T6 (2)	70,000	60,000	13	135

(1) Values determined on material examined earlier (ASh-62 crankcase, midsection)

(2) T6 indicates that the alloy is in the solution heat-treated and artifically aged condition.

(3) Recorded data from the Soviet Mechanical Engineering Encyclopedic Handbook, Vol. 4, Moscow, 1947.

(4) T4 indicates solution heat treatment followed by aging at room temperature.

TABLE II TENSILE PROPERTIES AND HARDNESS

Description	Yield Strength, 0.2% Offset, p.s.i.	Ultimate Strength, p.s.i.	Elongation, Per Cent in 2 in.	Reduction in Area, %	Hardness, Rockwell C (Converted from Rockwell A)
Tubing, 1.36" O.D.	121,000	132,500	10.0	--	27
	124,000	136,000	10.0	--	
Tubing, 0.98" O.D.	140,000	150,000	10.0	--	28
	137,000	149,000	11.0	--	
Clevis	--	--	--	--	32
Bolt (3/16" d. specimen)	88,500	120,000	20.0*	58.3	27
Nut	--	--	--	--	25
**	105,000-130,000	127,000-140,000	18-22		28

* Per cent in 1 inch.

** Normal expected values for U.S. steels of 0.30 per cent C, through hardened and tempered.

TABLE III SPECTROGRAPHIC ANALYSES OF SELECTED ALUMINUM COMPONENTS OF SOVIET YAK-11

Metal Sample No.	Description	Composition, Per Cent									Soviet Designation	U.S. Equivalent	Material Form	Thickness, Inch
		Si	Fe	Cu	Mn	Mg	Cr	Ni	Ti	Zn				
1	Skin, aft fuselage(5)	0.30	0.42	4.0	0.57	0.81(1)	<0.03	<0.03	<0.03	<0.1	D1	Alclad 17S	Sheet	0.030
2	Stringer, aft fuselage(5)	0.44	0.46	4.0	0.50	0.79	<0.03	<0.03	<0.03	<0.1	D1	Alclad 17S	Formed sheet	0.037
3	Underskin, starboard wing(5)	0.47	0.44	4.4	0.52	0.59	<0.03	<0.03	<0.03	<0.1	D1	Alclad 17S	Sheet	0.093
4	Stringer, starboard wing	0.35	0.46	4.1	0.53	0.96(1)	<0.03	<0.03	<0.03	<0.1	D1	17S	Extrusion	-
5	Built-up spar cap, starboard wing(5)	0.38	0.37	3.6(2)	0.58	0.96(1)	<0.03	<0.03	<0.03	<0.1	D1	Alclad 17S	Built up of sheet	0.187
6	Web, main spar starboard wing(5)	0.43	0.40	4.3	0.57	0.70	<0.03	<0.03	<0.03	<0.1	D1	Alclad 17S	Sheet	0.115
7	Rivets, starboard wing	0.11	0.36	2.5	<0.03	0.27	<0.03	<0.03	<0.03	<0.1	D19	A17S	Rivets	-
8	Bracket, landing gear support	1.1	0.44	2.3	0.47	0.43(3)	<0.03	<0.03	<0.03	<0.1	AK6	None(6)	Forging	-
9	Bracket, right wing attachment	0.92	0.35	2.4	0.53	0.47(3)	<0.03	<0.03	<0.03	<0.1	AK6	None(6)	Forging	-
10	Support, aileron control	0.97	0.50	2.4	0.55	0.78	<0.03	<0.03	<0.03	<0.1	AK6	None(6)	Forging	-

(1) Soviet specifications for alloy "D1" call for 0.4-0.8 per cent Mg.

(2) Soviet specifications for alloy "D1" call for 3.8-4.8 per cent Cu.

(3) Soviet specifications for alloy "AK6" call for 0.5-0.8 per cent Mg.

(5) Core-material analysis.

(6) The nearest equivalent U.S. alloy is 14S.

TABLE IV ANALYSIS OF SELEC
OF A SOVIET YAK-11

Metal Sample Number		Description	Chemical Composition (1) C	Mn	Si	Cr	Ni	Mo	Al	Ti	Cu	
11	A	Engine mount	0.29	1.00	1.3	1.1	<0.2	< 0.05			0.26	
	B	Clevis	0.36	0.93	1.30	1.12	<0.2	< 0.05	0.05	0.006	0.17	< 0
12	A	Bolt	0.34	1.00	0.9	1.0	<0.2	<0.05			0.14	
	B		0.35	0.97/1.00	1.24	0.96	<0.2	<0.05	0.04	0.005	0.15	<0.
13	A	Nut	0.50	0.58	0.27	0.14	<0.2	<0.05			0.31	
	B		0.45 est.	0.52	0.24	0.15	<0.2	<0.05	0.01	<0.005	0.26	<0.
14	A	Tube 1.36"O.D.	0.29	1.00	1.3	1.1	<0.2	<0.05			0.26	
		0.98"O.D.	0.30	0.90	1.1	1.1	<0.2	<0.05			0.24	
	B		0.30 est.	0.97	1.09	1.09	<0.2	<0.05	0.02	<0.005	0.19	<0.
15		Right rear fuselage wing attachment bracket	0.32	0.92/0.88	1.13	1.03	<0.2	<0.05	0.01	<0.005	0.26	<0.
16		Bolt retainer	0.20 est.	1.25	1.05	0.94	<0.2	<0.05	0.01	<0.005	0.13	<0.
17		Tube, male and female	0.32	0.88	1.13	1.03	<0.2	<0.05	0.01	0.005	0.03	<0.

1

B	V	Soviet Designation	U.S. Counterpart	Hardness Knoop	Hardness Rockwell C	Mfg. Method	Metallurgical Structure
< 0.001	<0.03 <0.03	30XΓC 35XΓC	None	-	32-34	forging Machined forging	Tempered Martensite Trace of Ti(C)N inclusion, balance sulfide, silicate, and alumina inclusions. Clean. Tempered martensite with undissolved carbides.
	<0.03	35XΓC					Carbides and ferrite indicate that the austenitizing temperature and/or time used in heat treating was insufficient for complete austenitization. Cd plated.
<0.001	<0.03	35XΓC	None	-	35	-	Trace of Ti(C)N inclusions, balance sulfide, complex silicate, and oxide inclusions. Somewhat dirty. Tempered martensite with undissolved carbides. Threads decarburized Bolt Zn coated.
	<0.03	50					Fine pearlite and ferrite. Cd plated.
<0.001	<0.03	45	AISI 1045	-	25		Clean. Ferrite and pearlite with some banding. Zn coated.
	<0.03 <0.03	30XΓC 30XΓC					Tempered Martensite Tempered Martensite
<0.001	<0.03	30XΓC	None	-	-	-	Undissolved carbides in tempered martensite. Clean. Few TiN inclusions.
<0.001	<0.03	30XΓC	None	239	18	Tubing	Very clean. Few sulfide inclusions. Ferrite with very fine pearlite to bainite, partially spheroidized. Indications are that this structure did not result from nearby weld.
<0.001	<0.03	20XΓC	None	-	23.5	-	Clean, mostly sulfide inclusions. Tempered martensite with undissolved carbides. Zn-Al coated.
<0.001	<0.03	30XΓC	None	-	-	-	Ferrite with very fine pearlite to bainite, partially spheroidized.

TABLE IV (Cont'd)

Metal ample umber	Description	Chemical Composition (1) C	Mn	Si	Cr	Ni	Mo	Al	Ti	Cu	B	V
18	Attachment bracket bolts for aluminum attachment bracket	0.39	0.93/1.03	1.28	0.98	<0.2	<0.05	0.02	<0.005	0.27	<0.001	<0.0
19	Nut	0.30 est.	1.05	0.92	1.06	<0.2	<0.05	0.02	<0.005	0.20	<0.001	<0.0
20	Washer	0.35 est.	0.58	0.30	0.23	<0.2	<0.05	0.02	<0.005	0.30	<0.001	<0.0
21	Exhaust duct Stop flange	0.20 est.	0.51	0.23	0.15	<0.2	<0.05	0.02	<0.005	0.25	<0.001	<0.0
22	Terminal fitting	-	0.5	0.4	14-16	8-10	<0.1	-	0.4	0.3	-	-
23	Duct tubing	-	0.5	0.4	14-16	9-11	<0.1	-	0.4	0.3	-	-
24	Engine Cowling Skin	-	0.5	0.4	14-16	8-10	<0.1	-	0.4	0.3	-	-
25	Doubler	-	0.5	0.4	14-16	9-11	<0.1	-	0.4	0.3	-	-

1) All elements were determined spectrographically except carbon, which was analyzed by wet-chemical methods or was estimated from the microstructure.

(Cont'd)

				Hardness			
B	V	Soviet Designation	U.S Counter-part	Knoop	Rock-well C	Mfg. Method	Metallurgical Structure
01	< 0.03	35XГС	None	-	38	-	Trace of Ti(C)N inclusions, few aluminum oxide inclusions, balance sulfides. Clean. Tempered martensite with undissolved carbides. Zn-Al coated.
01	< 0.03	30XГС	None	-	22	-	Same microstructure as the bolt above. Zn coated.
01	< 0.03	35	AISI 1035	260	21	-	Ferrite and pearlite with some banding. Zn coated.
01	< 0.03	20	AISI 1020	-	-	-	Low carbon. Ferrite and partially spheroidized pearlite. Banded structure; clean.
	-	X18H9T	AISI 321	-	-	-	Austenitic. Coarse grained.
	-	X18H9T	AISI 321	-	-	-	Austenitic. Fine grained.
	-	X18H9T	AISI 321	-	-	-	Austenitic. Fine grained.
	-	X18H9T	AISI 321	-	-	-	Austenitic. Coarse grained.

TABLE V POLYMER AND FILLER IDENTIFICATION FOR SELECTED PLASTIC PARTS FROM A SOVIET YAK-11 AIRCRAFT

Description	Color	Approximate Dimensions, in.				Polymer	Filler	Remarks
		Length	Width	Thickness	Other			
Landing-light cover. Curved clear plastic in a metal frame	Clear	-	-	-	-	Methyl methacrylate with phthalate-type plasticizer	None	None
Bomb-shackle components								
Long member	Grey brown flecked with yellow	-	1-1/2	-	-	Polyvinyl chloride, approx 16% plasticizer (phthalate type)	None	Sample had the appearance of a piece of tubing cut lengthwise. Block made by bolting two pieces together with the nuts embedded in one half. Marking on each piece was an egg-shaped raised portion with Б in narrow end of the egg. Entire marking was molded.
Rectangular block	Brown	1-3/4	1-1/8	7/16	-	Phenol formaldehyde	Talc, Fe_2O_3, $CaCO_3$, and $BaSO_4$	
Cockpit canopy and knobs								
Canopy	Clear	-	-	-	-	Methyl methacrylate, phthalate plasticizer	None	Curved clear plastic in a metal frame. 85-90% polymer, 10-15% plasticizer.
Round knob	Orange	-	-	-	1.0-dia. sphere	Methacrylate type	TiO_2, organic dye	None
Round knob	Black	-	-	-	1/2-dia. sphere	Methacrylate type	Carbon black	None
Engine control parts								
Valve handle	Red orange	See Remarks	-	3/8	See Remarks	Phenol formaldehyde	Wood flour	Valve handle was in the shape of a 5-leaf rose with O.D. of 2-3/8". It contained a round metal insert 7/8" dia. with a square hole 1/4" on a side.
Control knob, truncated cone	Red orange with yellow-orange band	1-1/4-dia. base	1-7/8-dia. top section	-	-	Ethyl methacrylate	See Remarks	Contained an alcohol-soluble dye to give it red-orange color, with a slight amount of inorganic material to increase opacity. Ring of ethyl methacrylate containing a ZnS pigment was inlaid around upper surface of cone. Ring was 7/8" in O.D. and 9/16" in I.D. Ring was yellow orange in ordinary light, but fluoresced orange under ultraviolet. There was no persistency.

TABLE V (Cont'd)

Description	Color	Approximate Dimensions, In.				Polymer	Filler	Remarks
		Length	Width	Thick-ness	Other			
Control knob in shape of hemisphere with small hole and keyway for attachment. At base of hemisphere was a circular piece inlaid to continue the hemisphere.	Red orange with yellow-orange inlay	-	-	-	1-1/4-dia. hemisphere	Ethyl methacrylate	See Remarks	Composition and performance same as above. Inlay was circle of about 1-1/4" dia. Fluorescent material was ZnS-CdS for both pieces.
Same as above without inlay	Red orange	-	-	-	1-1/4-dia. hemisphere	Ethyl methacrylate	See Remarks	Same as above, except that no fluorescent material was present.
A valve handle. An oval cylinder with two large holes at one end and a fluorescent inlay at the other.	Yellow	-	-	-	-	Ethyl methacrylate	See Remarks	Handle contained a yellow alcohol-soluble dye and a small amount of inorganic material. A curved inlay strip fluoresced green when excited by ultraviolet. Inlay had a short persistence. Fluorescent material was ZnS. Piece marking: CA·ZKAR.
Cockpit junction box cover. A rectangular piece with two raised round parts on one side and one raised round part on the other.	Black	2-7/16	1/2	1/4	Raised parts were 1/8" above rest of piece	Phenol formaldehyde	Talc, $CaCO_3$, and Fe_2O_3	Piece showed inscription ΡΛ - 70 49-3
Cockpit switch knob. An octagonal pyramid cut off about 1/2" from base. Base was circular piece. Sides were about 1/2" on edge.	Black	-	-	1/2	1-3/8 dia.	Phenol formaldehyde	Talc, $CaCO_3$, and Fe_2O_3	Knob had a raised arrow molded into top and pointing up, as indicated by position of marking 268 ↑ 70om.
Instrument case. A hollow cylinder threaded at the open end. Closed end contained two bib inserts.	Black	3-5/16	-	1/4 wall	3-1/8 dia.	Phenol formaldehyde	Carbon black, wood flour $MgSiO_2$, and $CaCO_3$	Piece had 3 markings: A at one bib, C at other bib. The marking, , also appeared in the center. 1-10% Na was found in ash of this sample. This amount could be due to incomplete washing of the Na fusion in manufacture of the resin.
Potentiometer from instrument panel. Two plastic parts. Cylindrical core upon which the resistance wire was wound	Purplish brown	1-7/16	-	-	7/16 dia.	Phenol formaldehyde	Talc and Fe_2O_3	None. (A knob, supposedly part of the potentiometer assembly, was not received for examination.)

TABLE V (Cont'd)

Description	Color	Approximate Dimensions, In.				Polymer	Filler	Remarks
		Length	Width	Thick-ness	Other			
Spacer to insulate core from metal frame	Brown	-	-	-	-	Phenol formaldehyde	Laminated cloth	None
Part of an oxygen regulator	Black	-	-	-	-	Phenol formaldehyde	Carbon black, wood flour, talc, Fe_2O_3, and $CaCO_3$	Piece, as received, was only a small part of original regulator.
Vibration damper under cowling	See Table I in Section I on rubber parts							
Cover for cockpit instruction card	Clear	2	4	0.042	-	Nitrocellulose	None	This was a sheet of nitrocellulose plasticized with camphor, probably made from film scrap It was clear with a slight yellow cast.
Guide for engine control cable. Plastic parts made in two sections each containing 1/2 the guide hole. The two pieces were bolted to each other as well as to a metal frame.	Brown	1-1/4 The above dimensions are for 1/2 of the guide.	5/8	5/16	1/4-dia. hole	Phenol formaldehyde	Laminated cloth	None
Cockpit emergency-light components (3 parts). Lamp holder and shield, cylindrical in shape with an opening cut into side	Black	3-1/2	-	-	1-5/8 dia.	Phenol formaldehyde	Talc and carbon black	None
Small button with shank	Red	1/2	-	-	3/16 stem dia.; 1/4 top dia.	Urea or melamine formaldehyde	Organic filler (see Remarks)	This button was excited by ultraviolet and fluorescent orange. Fluorescent material was organic in nature.
Dial	Orange	-	-	3/8	1 dia.	Urea or melamine formaldehyde	$BaSO_4$ and ZnS	None

TABLE V (Cont'd)

Description	Color	Approximate Dimensions, In.				Polymer	Filler	Remarks
		Length	Width	Thick-ness	Other			
Handle for emergency air valve. Star-shaped with six rounded points	Brown	-	-	7/16	1-3/4 dia.	Phenol formaldehyde	Cotton flock	None
Magneto components-starter coil. Coil was embedded in asphaltic-type material and enclosed in plastic cylindrical case.	Brown	2-1/2	-	1/16	2 dia.	Phenol formaldehyde	Talc and Fe_2O_3	None
Antenna grommet; 3 projections on periphery	Clear	-	-	3/16	1-7/8 dia.	Methacrylate	-	None

TABLE VI POLYMER IDENTIFICATION FOR SELECTED RUBBER PARTS FROM A SOVIET YAK-11 AIRCRAFT

Decription	Color	Approximate Over-all Dimensions, Inches					Polymer Identification	Remarks
		Length	Width	Thickness	I.D.	O.D.		
Cowling vibration damper	Black	6.6	0.85	0.06	0.2	0.3	Neoprene	No markings observed.
Instrument shock mount	Black	-	-	0.36 to 0.63	0.96	1.50	Natural	Molded inscription in upraised symbols: ... . 271-C2-6. Bad lateral cracks, some radial cracks. Excellent bond of rubber to metal sleeve.
Insulation on electrical wire								Item was a two-conductor cable. Insulation consisted of three layers. Outermost heavy rubber layer, inner rubber layer, and cotton thread loosely wrapped around conductor.
Outside covering	Black	40.5	-	0.066 to 0.092	-	-	Butadiene-styrene copolymer(1)	
Inside conductor covering	Dark Gray (Slate Gray)	40.5	-	0.037	-	-	Natural + butadiene-styrene copolymer(1)	
Bumper pad for cockpit canopy	Black	1.95	0.55	0.22	-	-	Polybutadiene	No markings observed.
Main fuel-line transfer-hose assembly - rubber layer	Black	12.7	3.3	0.02	-	-	Polybutadiene(2)	No markings observed on rubber layer. Coupling at one end of fuel line showed: 40, ; hexagonal head on inner sleeve showed: 7, 50, 19, 40, K; hexagonal head at other end of hose marked 40, 9, 9. Fuel line comprised of several layers; (1) outermost layer of spiral wound wire (0.045" dia.) with single strand of strong twist cotton running diagonally the length of line; (2) white tightly woven cotton fabric coated with 0.02" thickness of yellow-colored nitrocellulose; underneath side of fabric bore following markings stamped in blue ink; T'K] , L-5-50, 0; this layer was a single sheet wound around

TABLE VI (Cont'd)

Description	Color	Approximate Over-all Dimensions, Inches					Polymer Identification	Remarks
		Length	Width	Thickness	I.D.	O.D.		
								hose, with about 1.5" overlap; (3) strand of strong cotton or linen cord wound spirally in grooves made by (1); (4) wrapped rubber layer with 0.7" overlap, cemented; joint formed spiral around hose; (5) white tightly woven fabric [similar to (2)] 0.011" thick; (6) five thicknesses of transparent plastic, cellophane, tightly wound; thickness of each layer was about 0.004"; (7) white closely woven fabric, cotton, similar to (2), except for only 1" overlap; yellow-nitrocellulose coating; (8) wire (0.06" dia.) wound spirally on inside of hose at 0.25" spacing and lying in ridges made by (1).
Rubber grommet	Black	-	-	0.30	1.06	2.08	Natural	No marking observed. Some bad cracks noted.
Main oil return line - rubber layer	Black	14	5.1	0.024	-	-	Polybutadiene[2]	No mark noted. Metal coupling showed 40. Metal sleeve with hexagonal-head adapter painted olive green; sleeve marked with painted red arrow; hexagonal head marked with 55. Return line as received was saturated with brown oil throughout all layers. Except where noted, line was constructed similarly to main fuel-line transfer-hose assembly: (1) outside layer, wire, 0.06" dia.; (2) cotton fabric, 1" overlap; brown acetone-soluble coating, 0.023" thick; markings on inside of layer: 0 ; (3) strand of fiber; (4) rubber layer diagonally wrapped and cemented with 1" overlap; (5) woven fabric, cotton; (6) cellophane layers about 0.003" thick; (7) similar to (2), 0.02" thick; (8) spirally wound wire (0.06" dia.) lying in grooves made by (1).

TABLE VI (Cont'd)

Description	Color	Approximate Over-all Dimensions, Inches: Length	Width	Thickness	I.D.	O.D.	Polymer Identification	Remarks
Hose coupling from oil filter line								No markings observed. Rubber hose coupling attached to metal oil line with four metal clamps. Oil line was constructed as follows: (1) outer layer 1.1" herringbone-wave tape wound on bias; (2) matted coarse, animal fiber 0.05" thick; (3) dented, constructed nonmagnetic (white metal) pipe. Rubber hose coupling 5.5" long, 1.03-1.05" I.D., 1.40-1.43" O.D., and built as follows: (1) outside layer showed impressions of weave of Holland-type cloth; red rubber marking stripe 0.36" wide present for identification; (2) cotton cloth; (3) very thin bonding rubber layer; (4) cotton cloth, appears to be same as (2); (5) very thin bonding rubber layer; (6) cloth, appears to be same as (2) and (4); rubber bonded cloth layers totaled 0.04" thick; (7) inside rubber layer, 0.103-0.130" thick.
Outside layer	Black	5.5	-	0.05	-	-	Natural	
Inside layer	Black	5.5	-	0.103 - 0.130	-	-	Neoprene	
Hose from instrument vacuum line								No markings observed. Hose about 7.7" long, 0.15" I.D., 0.505 - 0.510" O.D. A 0.35" wide white rubber marking appeared in outer rubber layer. Construction of hose was: (1) outer rubber layer showed impressions (on diagonal) of Holland-type cloth, very dirty, very oily; (2) cotton cloth 0.18" thick; (3) very thin rubber bonding layer; (4) cloth, appeared to be same as (2); (5) inside rubber layer, 0.09 - 0.11" thick. One half of hose circumference had overlap of (2), (3), and (4).
Outside layer	Black	7.7	-	0.3	-	-	Natural, contains reclaim	
Inside layer	-	-	-	-	-	-	Natural, contains reclaim	
Chafing strip for fuel-tank top								No markings observed. Chafing strip was 9" long, 1.15-1.25" wide, and 0.55-0.70" thick. Five layers of rubber (3 of them foam) cemented together. Construction was: (1) outside rubber layer, impressions of woven fabric on both surfaces; (2) fine-pored foam rubber; (3) appearance same as (2), 0.15-0.20" thick; (4) same as (3); (5) appearance similar to (1), 0.042" thick.
Outside layer	Black	9.0	1.15-1.	0.034	-	-	Polybutadiene (2)	
Foam layer	Black	9.0	1.15-1.25	0.02-0.04	-	-	Polybutadiene(2)	
Cement	Pale Yellow	-	-	-	-	-	Neoprene	

TABLE VI (Cont'd)

Description	Color	Approximate Over-all Dimensions, Inches					Polymer Identification	Remarks
		Length	Width	Thickness	I.D.	O.D.		
Chafing strip for fuel-tank bottom	Black	35	1.7-2.2	0.1-0.2	-	-	Polybutadiene(2)	No markings observed. Fine-pored foam-rubber strip. On one surface, about 1/2" from edge of strip, 14 impressions of bolt or rivet heads.

1. Infrared analysis shows these products to be made of a styrene type of rubber. The per cent of styrene was not determined. This is the first indication that the Soviets are using a styrene type of rubber in aircraft parts.

2. All polybutadiene samples contained approximately 15 per cent of an unknown material, which is being further investigated.

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DEPARTMENT OF THE AIR FORCE
WASHINGTON, DC

23 June 2010

HAF/IMIO (MDR)
1000 Air Force Pentagon
Washington, DC 20330-1000

Bobby Sammons.
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Dear Mr. Sammons

Reference to your letter, undated (attachment 1) requesting a Mandatory Declassification Review (MDR) for Defense Technical Information Center (DTIC) documents:

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AD005736	AD005735
AD006796	AD004876
AD005809	AD003234
AD005808	AD004232

The review for the documents have been completed and the declassification has been downgraded to UNCLASSIFIED and copies are attached for your information.

Address any questions concerning this review to the undersigned at (703) 692-9979 and refer to our case number 07-MDR-076.

Sincerely

JOANNE MCLEAN
Mandatory Declassification Review Specialist

2 Attachments
1. Letter, Request for Documents
2. 10 DTIC Documents

cc: DTIC w/o documents